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Bulletin 87

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
JOSEPH A. HOLMES, DIRECTOR

HOUSES FOR MINING TOWNS

BY

JOSEPH H. WHITE

WASHINGTON
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PREFACE.

The organic act establishing the Bureau of Mines prescribes, among other provisions, the following:

> That it shall be the province and duty of the Bureau of Mines * * * to conduct inquiries * * * concerning mining * * * with a view to improving health conditions and increasing safety, efficiency * * *. That the director of said bureau shall prepare and publish * * * reports * * * concerning * * * the improvement of conditions, methods, and equipment, with special reference to health, safety * * *.

Although the actual loss due to an insanitary environment may not be as readily measurable as other losses, it is nevertheless real, and inquiries concerning improvements that go to shield the miner and his family from unnecessary sickness or discomfort plainly lie within the scope of the bureau's duties.

The author of this bulletin has visited the plants of many of the important mining corporations that control their own towns and carry on sanitary and welfare work. Much of the information contained in this bulletin is based on those visits, and too much credit can not be given to the mining officials for their friendly and helpful attitude toward his inquiries. This information has been supplemented by the observations of the mining engineers of the bureau and by data obtained by correspondence and from publications.

The bureau is indebted, for examination and criticism of the manuscript, to Morris Knowles, consulting sanitary engineer; Francis Feehan, Pennsylvania department of labor and industry; and J. B. Kuntz, architect.

JOSEPH A. HOLMES.

HOUSES FOR MINING TOWNS.

By JOSEPH H. WHITE.

INTRODUCTION.

In its investigations looking to the improvement of health conditions and the increase of efficiency in the mining industry, the Bureau of Mines, in cooperation with the Bureau of Public Health, is studying sanitary conditions in and about mines with the intent of pointing out how those conditions that are a menace to the health of the miner may be most efficiently removed or remedied. An outline of sanitary betterment work at mining villages in the Birmingham district of Alabama has already been published by the bureau,[a] and in this bulletin are presented suggestions on the planning of mining towns and the construction of miners' houses. The bulletin does not pretend to be a treatise on the so-called "housing problem," and mentions sociologic issues only incidentally.

It is assumed that the influence of proper shelter on health is understood and that not a lack of appreciation so much as a lack of knowledge of the best remedies is responsible for many of the undesirable conditions that exist at mining towns. The purpose of this bulletin is to supply facts on the building of well-lighted, well-ventilated, warm, attractive, and economical houses for miners, these houses being assumed to be units of an industrial village or town the building and management of which are under the control of a corporation, so that special conditions hold which do not apply to houses built and owned by individual miners.

From this it is not to be inferred that the company-controlled town is the best system or the only one in vogue. The discussion of this side of the subject in all its phases is too involved to be included in this paper. One element in favor of the company-controlled town is its possible immediate responsiveness. Hence this assumption. Also the assumption is made that a new isolated town is being built, and hence the selection of the site, the arrangement of the streets, and the situation of the houses are discussed before the house itself is treated, for one of the most important factors in obtaining an economical sanitary house is a well-selected town site. Many of the suggestions, however, may be applied in improving conditions in existing towns, in building new houses in old towns, or in repairing old houses. Emphasis must be laid on the fact that as a rule a mining village has a shorter life than a manufacturing town.

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[a] Woodbridge, D. E., Sanitation at mining villages in the Birmingham district, Ala. 1913. 27 pp.

Economy is emphasized frequently because the discussion is predicated upon the assumption that the miner himself is to pay for all that he gets. House rent will doubtless be expected to bring in a reasonable return on all money invested in streets, sidewalks, water supply, sewer system, and houses; in other words, the town is to be run on a business and not on a paternal or charitable basis. "Fair and reasonable" precludes, of course, the idea of excessive returns. Some companies do not consider it good policy to realize as high a rate of interest as an independent realty company would be warranted in realizing. Under some circumstances part of the town improvements might be charged as "expense of the industry," that is, to the consumer.

The isolation of a mining town introduces a unique responsibility. As the miners are practically obliged to rent the company houses, the officials of the company ought to scrutinize all expenditures involved so that house rent may be reduced to a minimum. In a way the town builders are placed in the position of trustees. They determine, within certain limits, what proportion of a man's wages shall be spent on house rent. This consideration should restrain fanciful and unnecessarily expensive building; the other extreme should likewise be avoided. True economy should be distinguished from cheapness. Ugly, insanitary, uncomfortable shacks should not be built even if, because of their cheapness, there is a demand for them from tenants. The obligation of the industry to society as a whole as well as to the tenant ought to forbid this. A cheerful, strong, healthy, virile race will not rise out of the filth and squalor of cheap hovels. An insanitary environment often does its damage slowly and silently; vitiated air does not, like mine gas, announce its deadly work by an explosion. As Talbot[a] says:

> Health depends in part on freedom from infection. The probability of obtaining that freedom will be greatly increased by maintaining the body at a high state of vigor, or "vitality," as it is popularly called. This implies the promotion of all agencies which have to do with the physical well-being as well as with the control of sources of infection.

Many men realize that in building houses for their workmen they are invested with a peculiar responsibility that must be wielded wisely, and in large developments they call into consultation the landscape architect, the sanitary engineer, and the building architect, as well as the mining engineer.

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[a] Talbot, Marion, House sanitation, 1913, p. 8.

TOWN SITE AND ARRANGEMENT OF TOWN.

IMPORTANCE OF TOWN SITE.

The general practice in the past has been to build the miners' houses near the mines, and in selecting a site for a mining plant the desirability of the locality for town building received slight consideration. So long as crude, ugly, insanitary mining "patches" or "camps" (see Pl. I, *A*) prevailed this course of procedure went unchallenged, but the rise of the modern mining town necessitated changes, and to-day the policy is to consider the town site in connection with and as an important factor in the situation of the mine plant. Moreover, if the mine plant must be built in a place that is undesirable for a town site it is no longer considered essential to build the town close to the plant.

ADVANTAGES OF ESTABLISHING TOWN NEAR PLANT.

Numerous elements affect the desirability of a town site, and local conditions will modify the choice in each case; nevertheless, there are certain general considerations that apply in making the selection. In the first place, some of the advantages gained by building the town adjoining the plant will be considered. Perhaps the most important of these advantages is that the miners may live near their work, wherefore they do not have to get up so early in the morning and in returning home at night do not have to walk so far in their damp working clothes, perhaps in the cold or wet. It should be kept in mind that a miner may have to walk a considerable distance, sometimes over a mile, before reaching the surface.

At mines where the company owns the store and where wages are advanced before pay day it is convenient for the women and children to have the house, the time office, and the store close together.

There is an advantage in having the houses near in time of breakdown or disaster, and men holding responsible positions such as those of mine foreman, fire boss, or watchman, should be within call at all times.

Building the town and the plant at one place simplifies the shipment and hauling of building material and reduces the cost of supervision. The proximity of the houses to the power plant is to be considered in connection with heating, lighting, and fire protection. In some cases it may be of advantage to have all surface rights contiguous in order to avoid litigation about roads, power-transmission lines, or water pipes.

These are important considerations, but the tendency has been to overestimate their significance; besides, new mining methods make many of them less important now than formerly. For instance, shifts are shorter than they were; underground transportation of men to their working places is more developed; wash and change houses are being erected so that the men may leave their damp working clothes at the mine; more frequent pay days are coming into vogue, and company stores are not as common as they were.

POSSIBLE ADVANTAGES OF BUILDING TOWN SOME DISTANCE FROM PLANT.

If latitude is allowed in the search for a town site, a larger plat of gently sloping land may be found which will offer many advantages. The town may be laid out contiguously rather than in separated clusters of houses as is frequently done. The cost of streets and surface drainage systems may be lessened by the ground being less rough, and unsightly hillside houses with expensive foundations may be avoided. Single houses may be erected with large yards, insuring sunshine, good air, and fire protection. Fertile soil may be found, making possible kitchen gardens with their multifold benefits. A large plat of land may be available for truck gardens, chicken farms, or pasturage, all of which will help to reduce the cost of living and offset the difficulties incident to the irregularity of mining.

Latitude in the choice of a site may allow the utilization of a lake, a river, or a spring, which may simplify the drinking-water-supply problem (see Pl. I, *B*), or may prove an asset as a source of healthful recreation. Athletic fields, picnic grounds, and wooded areas may be possible.

By building the town at a distance from the mines many of the dangers, nuisances, and necessarily unsightly features incident to mining may be avoided. The dangers and delays due to railroad crossings will be minimized; and in the case of a coal-mining town the noise, smoke, and dust from the tipple, breaker, coke ovens, washery, and boiler plants will be avoided, and "slate" dumps and culm heaps will not be before one's eyes year in and year out.

The maximum permissible distance between town site and mine will depend largely on the proximity to a railroad or an interurban electric system. If the men have to walk to their work the character of the roads and short-cut foot paths is important. A little money invested in footbridges, steps, and clearing away obstructions may greatly improve conditions. The long distances many men are willing to walk to work, in order to obtain the advantage of owning and living in their own homes, proves that nearness to work may be offset by other factors.

In the above discussion the opening of a single mine whose operation required 200 or 300 houses was under consideration. Another case arises when the mineral development requires or ultimately will require a large number of openings a mile or so apart, as in drift mines. Suppose 50 to 100 homes are needed for each

A. OLD-STYLE, CHEAPLY CONSTRUCTED, AND NEGLECTED COMPANY HOUSE.

B. DRINKING-WATER RESERVOIR IN PROCESS OF CONSTRUCTION AT JENKINS, KY.

C. THREE-ROOM MINER'S COTTAGE AT DEWMAINE, ILL.

opening, with a total of 800 or 1,000 houses in all. The desirability of assembling these at one place and building one large modern town (fig. 1) is worthy of careful study. The magnitude of such a town would warrant such features as an efficient traction system, a suitable water supply, a sewer system, paved streets and sidewalks, a lighting system, better sanitary laws and regulations, garbage collection and disposal by incineration, salvages realizable by utilization of wastes, bigger stores, better schools, hospitals and cemeteries, a playground, amusement halls, a dancing pavilion, a theater, and more varied means of entertainment; in short, the advantages of a highly organized city as compared with those of a village; and as the company controls the construction of the town, if not the management, many city evils may be forestalled.

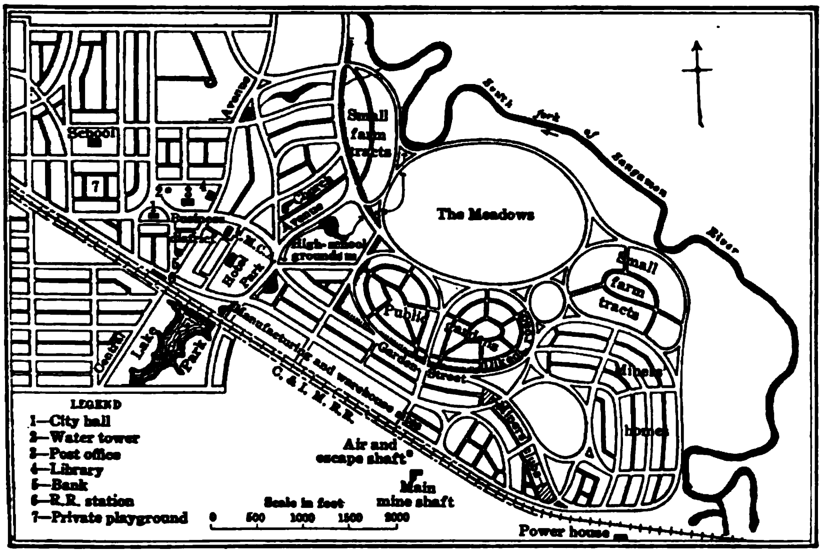

FIGURE 1.—Map of model mining town in Illinois.

NECESSITY OF A MAP.

After the site for the town has been determined the layout of the streets and alleys and the size and arrangement of lots must be considered. For this reason a topographic map of the site should be made showing contour lines at not more than 5-foot intervals, if possible, all watercourses with high and low water levels, wet places, soil conditions, the name and diameter of all large or sightly trees, Government section lines, and similar information. With the aid of such a map a number of arrangements may be investigated and their relative costs and advantages may be compared, and when field inspections are made a more vivid and comprehensive mental picture can be formed. The advantages derived from having a map of this kind will well repay the cost of making it.

STREETS, GUTTERS, SIDEWALKS, AND ALLEYS.

STREET SYSTEMS.

Even on a level area the rectangular street system is not adopted as much as formerly because of the many pleasing effects obtainable with winding streets. Winding streets permit a larger number of houses to take advantage of such natural features as favorable

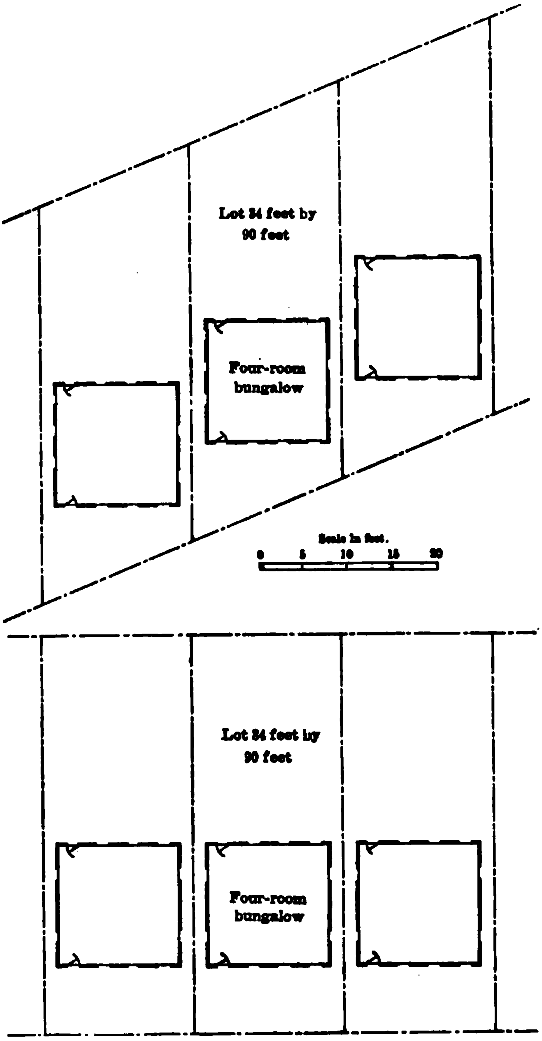

FIGURE 2.—Diagram showing advantage of diagonal street for closely grouped cottages. Houses arranged as in upper view have more air, light, and sunshine, and better outlook than those arranged as in lower view.

exposures and prevailing winds, and a greater variety of viewpoints is attainable, especially on the concave side of curves. Numerous parks and grass plats may be developed. On a hilly site contour streets are, in addition to these advantages, most economical; easy grades may be obtained with less cut and fill; culverts, bridges, surface drainage, and sewer systems will cost less. With this system the lot will slope toward the street, so that the ground line of the front of the house will be level, which greatly improves appearances.

In some cases it may be necessary to crowd cottages closely. In such, more sunshine, better ventilation, and a better outlook will be afforded if the houses are offset by means of a diagonal street than if the regular perpendicular street system be followed (see fig. 2).

In some localities the street system of the proposed town may have to be coordinated with the public-land system of roads, in which case some streets must run north and south. In the main business part of the town practical purposes may be better served by straight streets.

WIDTH OF STREETS.

In the average mining town the vehicular traffic in the residential district is not heavy, so that a narrow well-surfaced street, with an effective gutter and paved sidewalk, provided the building line is well back from the street, suits conditions better than wide streets and poor sidewalks. As a fire-protective measure streets have been made very wide in some mining villages; hence it is evident that the water-supply system will affect the width of the streets.

NAMING OF STREETS.

The streets should be named not only on the maps in the engineer's office but by signboards in prominent places. This is a thoughtful improvement and costs very little. It goes without saying that the town should not be designated by a numeral in correspondence or referred to in conversations as a "camp" or "patch."

CONSTRUCTION OF SIDEWALKS AND GUTTERS.

The following directions are often followed for making cement sidewalks. The ground is leveled off about 10 inches below the finished grade, and if necessary is well settled by ramming. A 5-inch foundation of coarse gravel, broken stone, or coal ashes is placed and rolled. A 3-inch layer of concrete, made from one part cement, two parts sand, and three parts stone and mixed dry, is laid on this foundation and covered with a 1-inch surface coat made of one part cement and one part sand. The sidewalk should drain toward the gutter, with a slope of 1 in 10, and should have expansion joints every 5 or 6 feet.

Well-paved sidewalks are recommended for comfort and cleanliness. They do not have to be as wide as city sidewalks. There is perhaps more comfort in using a well-paved sidewalk 2½ or 3 feet wide than one of much greater width less carefully built.

In case there is no underground sewer system the street gutters should be designed with a view to removing house wastes, such as kitchen slops and wash water, as well as surface drainage. For this reason they should be made of concrete, box shaped, and smooth surfaced with rounded corners.

ALLEYS.

Alleys, preferably narrow ones, should be provided, as they make a lot more private and are convenient. In a well-administered model town none of the notorious evils of the alley need be allowed to develop.

Some town planners disapprove of alleys because the expense of fences is increased, more paving is required, and the alley is apt to become unsightly.[a]

DIMENSIONS OF HOUSE LOTS.

Where there is plenty of suitable land each cottage should have a large yard. It is generally better to apportion this area by depth rather than frontage, in order to reduce the cost per lot for street improvements. However, the houses should not be crowded together; there should be sufficient distance between them to insure good light, ventilation, privacy, and fire protection. This distance depends to some extent upon the height of the house. One-story houses may be spaced closer, if necessary, than two-story houses, and conditions may be relieved somewhat by alternating one and two story houses.

SITUATION OF HOUSE ON LOT.

Better lighting often may be effected by varying the distance between the front of the house and the street line, in which case two-story houses should be set farther back than one-story houses for the purpose of equalizing the street view. Similarly it is a good plan not to build the houses on the two sides of the street directly opposite one another. If the houses are staggered, better circulation of air and more interesting outlooks will be furnished. (See fig. 4.)

If there are to be no front fences and if the houses are practically on the street level a greater distance between the street and the house is necessary than if the reverse be true. Most advantage may be taken of a necessarily small distance by laying the sidewalk adjacent to the gutter rather than by having a 6 or 8 foot grass plat between the gutter and the sidewalk, as may be justified under different circumstances.

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[a] See remarks of Morris Knowles, The Proceedings of the Third National Conference on Housing, Dec. 3, 4, and 5, 1913, p. 111.

HILLSIDE HOUSES.

On many sites the grading of house lots is so expensive that some houses must be built on sloping lots. Every economical method of relieving the unsightliness of these hillside houses should be employed. As has been pointed out contour streets improve conditions somewhat because the ground line on the exposed side of the house is level. Excessively steep lots should not be used, as the cost of foundations, steps, and building is too great and the house is not satisfactory to live in. With the idea of utilizing such lots, one company attempted to develop a cheap five-room house in which the front and the back contained a different number of stories; on the high side of the street the house had three stories in front and two in the back; whereas on the low side the arrangement was reversed. The construction of these houses proved very expensive and was discontinued.

The houses on the low side of the street should be brought up to the level of the street grade, if possible. This can be done by shifting the retaining wall, which is so often placed on the property line, back to the house line. Houses on steep lots should be shallow, as this greatly reduces the appearance of the inequality in height between the front and back of the house. Two-story houses on the low side of the street will equalize appearances (see fig. 3). The appearance of the houses on the high side of the street may be improved by placing the veranda on the side rather than on the front, thereby reducing the depth of the building, or by changing the direction of approach of the front steps. Figure 4 shows a suggested arrangement of houses and lots.

TYPES OF HOUSES.

MATERIAL OF CONSTRUCTION.

The material from which the houses are built depends largely on local conditions. The availability of the material, whether it be lumber, brick, stone, or cement, is important because of its bearing on cost. The estimated life of the town determines how much stress should be laid on the durability of the building material. Climatic conditions may determine the selection of a cold-resistant or heat-resistant material and the form of construction to be used. The prevalence of high winds, earthquakes, rain, and atmospheric humidity must be considered. The spacing of the houses, one from the other, the cost of fire protection, the fire hazard, and the insurance rates influence the choice of building material.

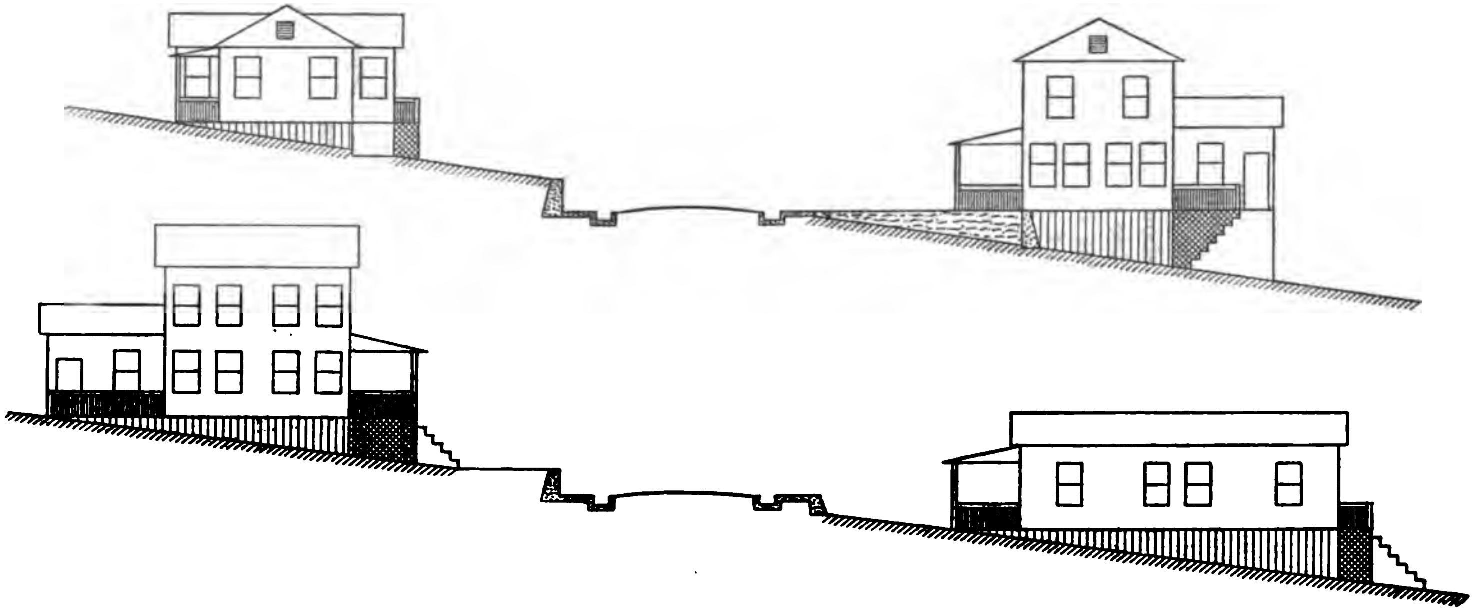


FIGURE 3.—Right and wrong methods of arranging hillside houses. Upper view shows correct arrangement, with one-story house on high side of street.

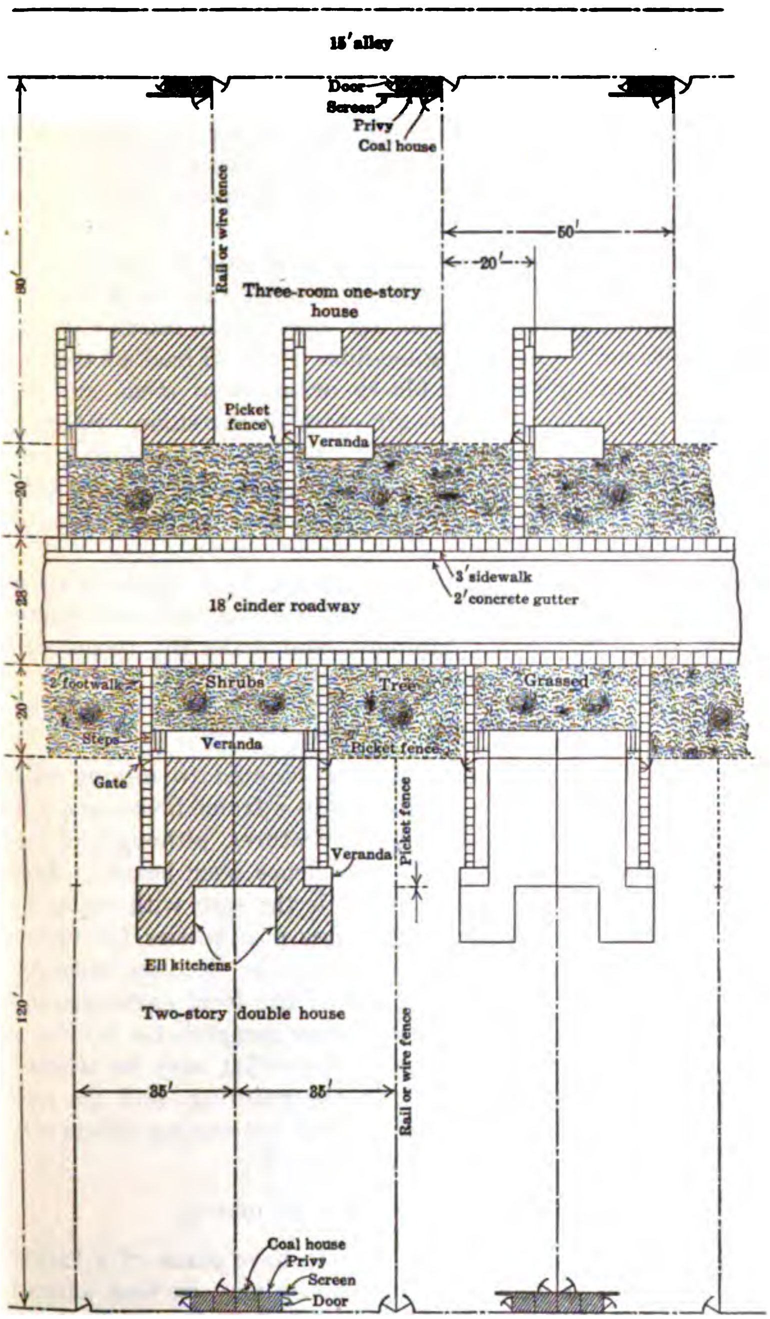


FIGURE 4.—Suggested arrangement for houses and lots: Picket fence in front, rail or wire fence along sides and in rear, footwalks along side of house, houses not directly opposite one another.

MASONRY HOUSES.

Various types of masonry houses are being erected at towns connected with mining and metallurgical industries. Under special circumstances brick and stone (generally sandstone found on site and easily quarried) houses have been erected for the use of miners. Recently some attractive homes have been made from poured concrete (Pl. II). These are very durable, fireproof, and, to a large extent, vermin proof.

Unless some precautions are taken houses built with solid masonry walls will be damp and moisture will condense on the inside. Brick walls are generally built with an air space in the interior to prevent this. Sometimes an insulating medium is placed back of the plaster. Forms for making concrete blocks or artificial stone are usually made so that there will be an air space in the stone. Special machines are on the market whereby a hollow concrete wall may be poured. Hollow tiles are now also being used for finished exterior walls. These have been used for some time on interior nonload-bearing walls.

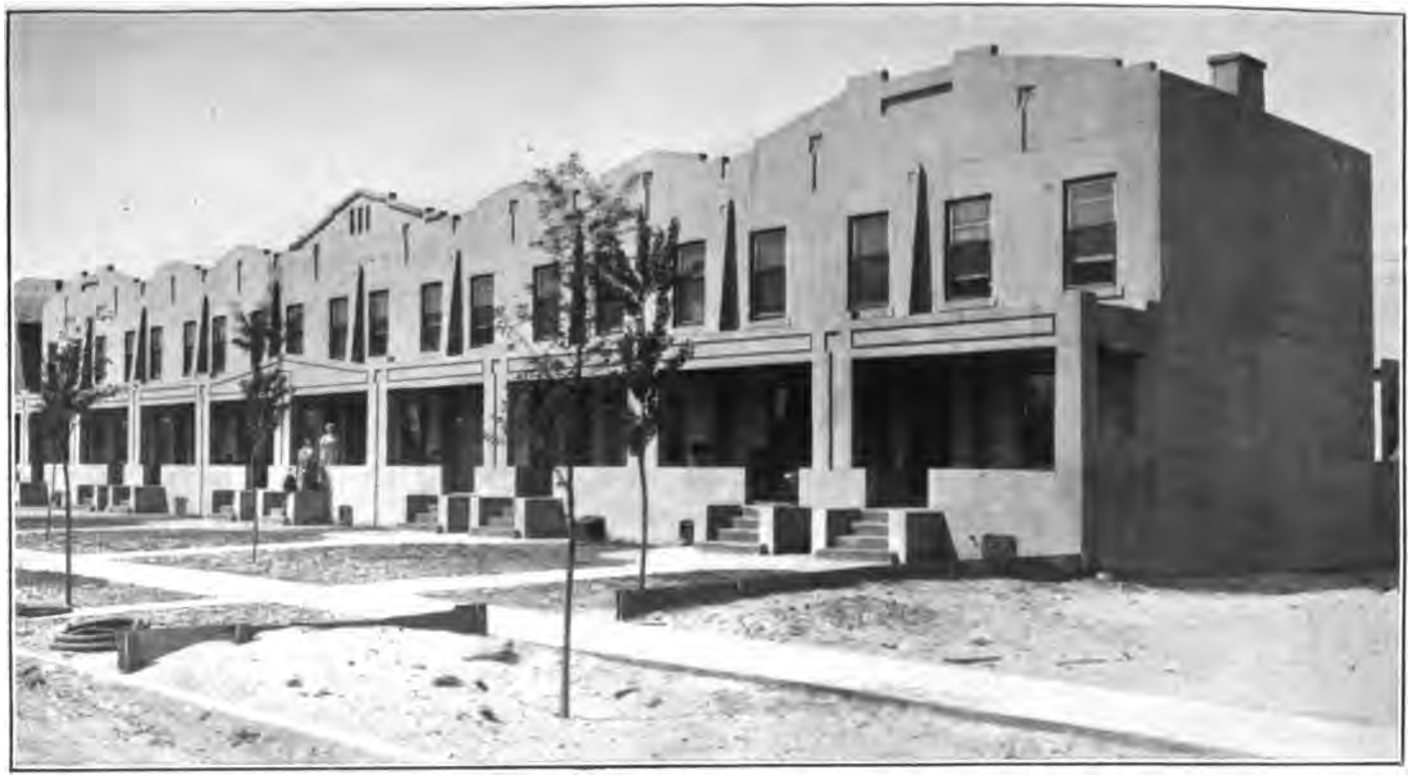
The idea in all of these types is to establish an insulated air space (similar to a thermos bottle) between the outside and inside wall surfaces, so as to prevent dampness and make the rooms warmer in winter and cooler in summer.

ADVANTAGES OF FRAME HOUSES.

Generally, the frame house is best adapted to mining villages. More variety of design can be attained in a frame house, and it lends itself to more economical decorative features, although, of course, health and comfort are to take precedence over beauty. Another desirable feature of the frame house is the ease with which it can be enlarged. In designing small houses possibilities for future extension should be provided; many a miner becomes strongly attached to his house or some feature of the local environment, and if his house can be enlarged to meet new demands he is often more contented. As regards color, the variety that may be attained by different combinations of colors in the painting, and the need of periodic painting with its cleansing and renovating effects may be regarded as an advantage of the frame house.

ADVANTAGE OF VARIETY IN DESIGN.

In building on a lot it is desirable to have plans of a variety of houses available in order that the house may be best adapted to the lot on which it is placed. Variety of design not only has a utilitarian purpose, but improves the appearance of the entire town. There is also an economic reason which pleads strongly for



MULTIPLE-TENEMENT DWELLING OF CONCRETE CONSTRUCTION. FIVE ROOMS EACH; ALL MODERN CONVENIENCES. GARY, IND.

variety in houses; namely, differences in rents. The decision as to what proportion of his income a miner should spend on house rent is determined by a number of considerations. Racial characteristics, size of family, domestic habits, social and educational aspirations, past obligations, all affect the question. Each case can best be settled by each individual family, and means of meeting different desires should be provided within certain limitations.

PROPORTION OF TYPES.

After the variety in style of the houses for a new mining town has been determined, the next question that arises is the number of three, four, five, or six room houses that shall be built, and how many houses shall have single, double, or multiple tenements. This question can be decided only after carefully collected statistics have been interpreted with sound judgment. Local investigations must be made; the character of labor must be predicted; the percentages of married and unmarried men on neighboring pay rolls should be ascertained; and the sizes of miners' families should be recorded. Observation indicates that miners' houses in the past have been built entirely too small. In correcting this defect incongruous additions have been built, which probably gave rise to the term "mining patch."

TWO-STORY HOUSE.

As the number of rooms in a one-story house increases, the number of exposed sides to each room decreases. In a one-room house the room would have four sides completely exposed; in a two-room house each room would have three sides; and in a four-room house two sides exposed; and when a fifth room is added only one side of it may be exposed. Therefore, when the rooms reach a certain number it becomes advisable to build two-story houses, not only for improved lighting effects, but also because it cheapens the proportionate cost of foundation, roof, and of land occupied.

A two-story brick cottage is shown in Plate III, *A*. The plan of the house is shown in figure 5.

DOUBLE-TENEMENT HOUSES.

Double-tenement houses have in the past been used to a large extent in mining towns, especially in northern climates, where expensive cellars are required. It is generally necessary to make double-tenement houses two stories high. Each tenement should be made as private as possible. Separate front porches are highly desirable. The yards should be fenced off and individual privies and coal sheds built. Tenements should be side by side and not one over the other.

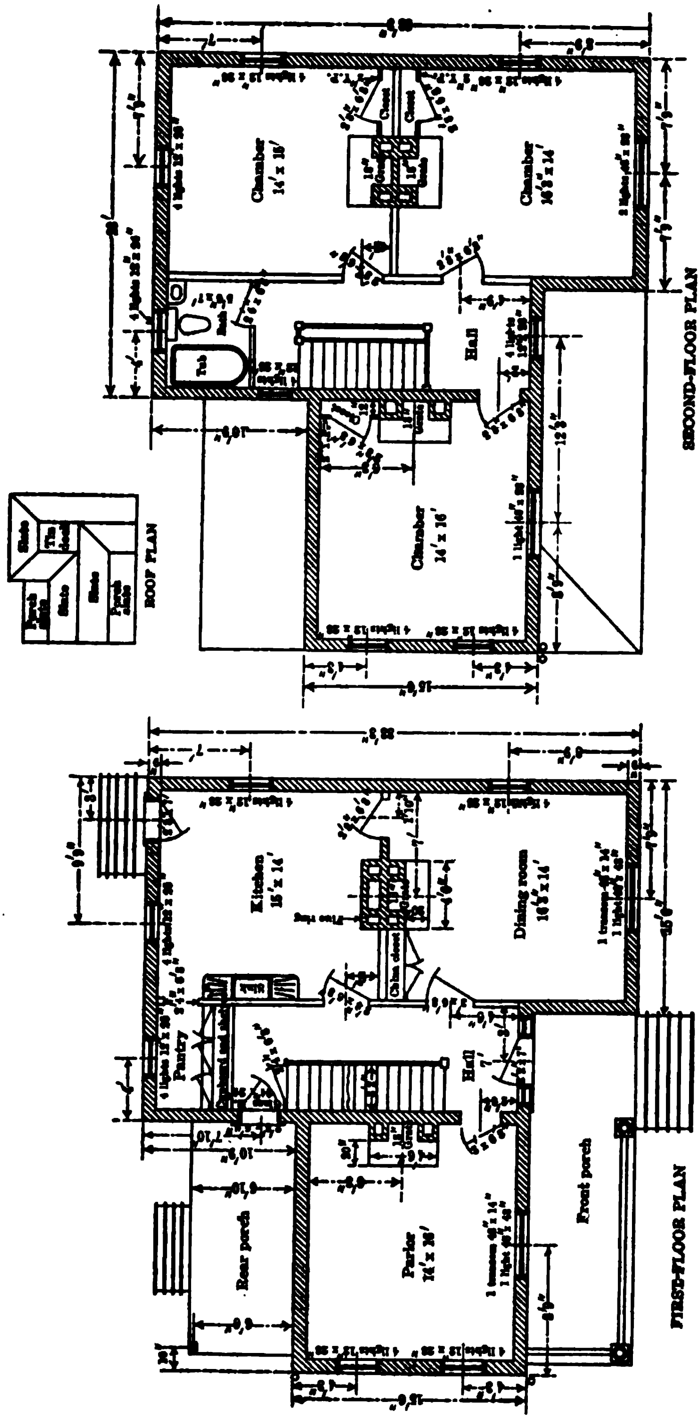
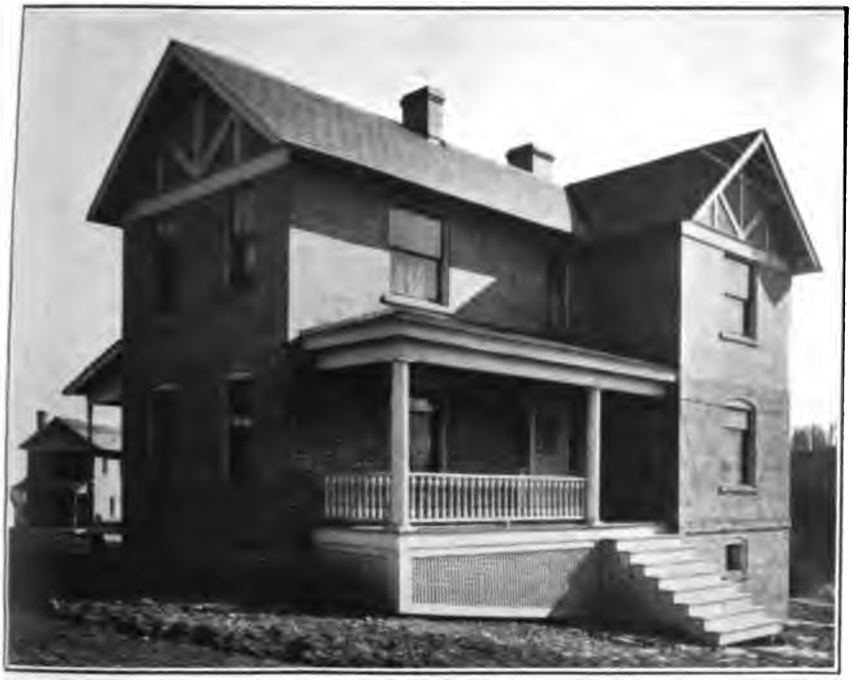
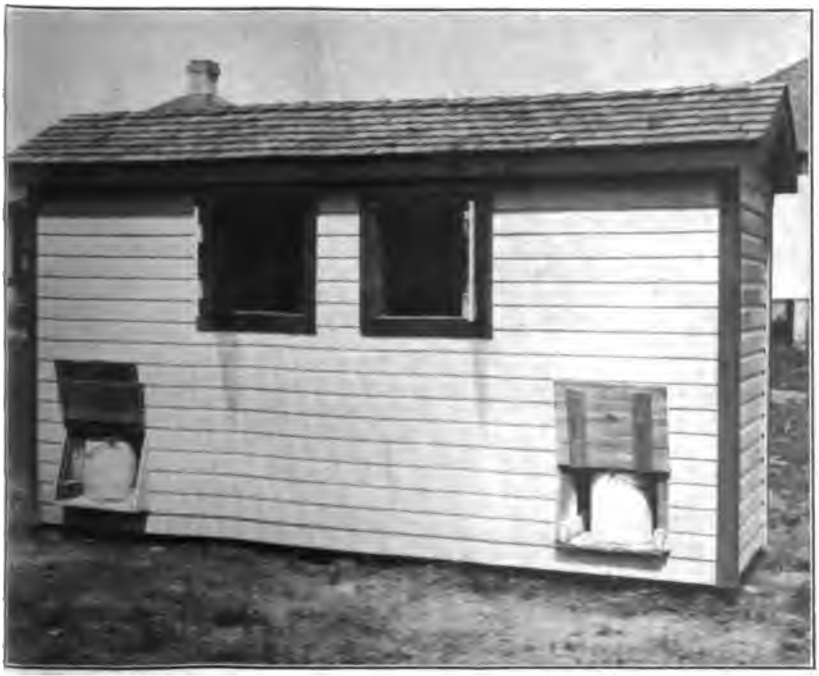


FIGURE 5.—Floor plans of two-story brick house.



A. MINER'S BRICK HOUSE AT MARIANNA, PA.



B. REAR VIEW OF COMBINATION COAL BINS AND PRIVIES FOR TWO DWELLINGS. THE LOWER DOORS ARE SET AT AN ANGLE SO AS TO CLOSE TIGHTLY.

MULTIPLE-TENEMENT BLOCKS.

A multiple-tenement block may be a building two or two and one-half stories high, extending along the street front so that 6 to 10 homes are under the one roof. This type of dwelling is economical because of the saving in side walls and may be necessary where land frontage is scarce. The critical consideration in its adoption is climatic conditions. In a cold climate the practice of building a number of two-story houses of identical design with narrow passageways (4 or 5 feet) between the houses is undesirable. Little sunlight reaches the rooms on these blocked sides; in fact these sides are generally windowless. It would be better to combine these houses and omit the narrow passage entirely and enlarge the window areas in front and back. The tenement block should never be built more than two rooms in depth, except, perhaps, for the extension of a kitchen ell in the rear. Tenement blocks should be built preferably on a street that runs north and south, so that the exposed side of the rooms will have the advantage of as much sunlight as possible. The cutting off of the convenient entrance to the back door is not a serious objection. The combining of eight of these houses may permit the blocks to be separated by an interval 30 feet or more wide, thus furnishing two tenements in every eight with plenty of light and sunshine.

In warm climates, however, the important consideration is to get a cool, well-ventilated house, and individual houses, even though spaced closely, help this. Even if sunlight can not penetrate these narrow passageways, windows should be placed therein for ventilating purposes. Privacy may be attained by not placing windows directly opposite each other or by using ground or other translucent glass.

ORIENTATION.

The direction in which the house faces is important in self-contained houses as well as in multiple-tenement dwellings. Every effort should be made to have the living rooms that are most used on the south and east sides. The north and west sides are more cheerless in winter and more uncomfortable on warm summer evenings. The halls, stairways, and less used rooms should be on these less desirable sides.

KITCHENS.

In some places it was a common practice in the past to build the kitchen entirely separate from the rest of the house. It is not believed the best conditions result from separating the kitchen and the house; ultimately the intervening space is roofed over, then one side will be closed, and finally the kitchen becomes a part of the main building.

The kitchen in a miner's house should be made much larger than has been the practice in the past; in fact, the kitchen should be the largest and most pleasant room in the house. It is the center of all home activities. The miner's wife spends a large part of her life in the kitchen; it is used as the family dining room; the children play there and around the back door. Neighbors are entertained in the kitchen. In the absence of a washhouse, it is used as a bathroom. On cold winter nights the family circle is around the kitchen stove. These remarks apply notably to the smaller houses, in which the living room is often converted into a bedroom. Statistics as well as observations prove this. Of 2,371 miners' families investigated by the Immigration Commission[a] 43.5 per cent used all but one of the rooms in the house for sleeping purposes, and 41.1 per cent used all but two rooms for sleeping purposes. Of course, it would be desirable if every miner—in fact, every workingman—could have a dining room, a living room, and a parlor, in addition to his kitchen, but this is not always practicable under existing conditions.

WINDOWS, DOORS, AND ARTIFICIAL LIGHTING.

In this bulletin the discussion of windows, doors, artificial lighting and heating, and interior finish precedes the discussion of foundations, chimneys, framework, and roof. Although this order is illogical from the builders' point of view, it is the logical order as regards the health of the people who are to occupy the house. It is felt that many advantages have been abrogated because of a desire to conform to construction practices or through fear of violating fixed standards, such as placing windows with a view to symmetry rather than with regard to the interior arrangement or the lighting effect. It is desirable that the plan of the house should be developed from the room out and not from the foundation up.

WINDOWS.

MORE SUNLIGHT IN THE HOME.

The part played by sunlight and fresh air in insuring good health is often dwelt upon, but practical and specific methods of introducing a maximum of these into a cottage are seldom furnished. Because lighting and ventilating an individual house, as compared with a crowded city tenement, is simple, the tendency has been to slight this subject, with the result that the prevailing condition is far from perfect. The lightsomeness of a miner's cottage deserves special consideration. As the miner's occupation necessitates many sunless hours, every effort should be made to bring as much sunshine into his home as possible and to reduce to a minimum the need of artificial light.

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[a] Immigrants in industries: Reports of the Immigration Commission, 1910 (Senate Doc. No. 663), vol. 6, 1911, p. 184.

The explanation frequently given for not having more windows is that they would make the house more difficult to keep warm in cold weather. Climatic conditions should greatly influence one's judgment in this matter, and it must be remembered that warmth and comfort are essential as well as sunlight, but excuses should not be allowed to masquerade as reasons. A house can be well lighted and still be kept warm. Open foundations, single floors, unceiled rooms, leaky roofs, loose windows, and sagging doors are the chief reasons for cold, uncomfortable houses, and if larger windows will necessitate a correction of these defects, then they bring a double blessing.

CONTROLLED VERSUS ACCIDENTAL VENTILATION.

Some good from the above construction defects has been claimed because they were all that furnished many occupants with fresh air on account of their prejudice against opening windows. This claim is not supported by modern ventilating ideas. "Air-conditioning" is the latest word in ventilating parlance. It signifies that the amount of air furnished should depend upon whether the occupant is actively engaged in housework, or sitting quietly eating or reading, or is sleeping under warm bedclothes. "Controlled" ventilation by properly placed doors and easily opened windows is needed, and not "accidental" ventilation.

WINDOW AREA.

No hard and fast rule can be given for the proportion of wall area that should be used for window space. The climate, building material, interior finish, shape of room, number of sides exposed, and the use of the room all affect the proportion. One feature that may serve as a guide is the common inadequacy of window area in the past. Those mining companies that are changing the type of construction of their houses are especially cautioned. Some companies have recently built clapboarded and plastered houses and did not increase the window area from that used with old methods of construction, with the result that the rooms are very warm and close in summer.

POSITION, SPACING, AND SHAPE OF WINDOWS.

It will be of help to keep in mind the three distinct functions of a window, namely, air, light, and outlook; and the position of the window should be such that all these purposes are fulfilled to the best advantage. The arrangement of the furniture in the room should be forecasted so that the windows may be placed with respect to the arrangement of the bed, bureau, tables, looking-glasses, etc. In placing bedroom windows it should be remembered that bedsteads are from 6 feet 6 inches to 6 feet 8 inches long and from 3 to 5 feet wide. If the room has two sides exposed, advantage should be taken of this feature and windows placed in both exposed sides. One of the fundamental considerations emphasized in designing a house is the necessity of having exposed sides for this very reason. In a balloon-frame house it is desirable to have the windows in the second story directly over those in the first story.

The shape of the opening is important, and in building a large number of houses the use of sashes not of standard sizes may be justifiable. A tall, narrow window is more effective than a short, wide one, and the opening should extend well up toward the ceiling. This permits the light to penetrate farther into the interior of the room and reduces the reservoir of stagnant air between the top of the window and the ceiling. It also allows greater wall space for furniture.

On all window casings a strip of sheet lead should be placed along the top on the outside. Otherwise water may leak in during rains and stain the curtains or shades.

GLAZING.

Ordinary window glass is made in two standard thicknesses, known as " single thick " and " double thick," the former being about one-sixteenth inch and the latter one-eighth inch thick. Although the latter costs a little more than the "single-thick" glass, it is much stronger and is a better insulator against the cold. Single-thick glass should never be used in panes larger than 24 by 24 inches.

Glass should be set with putty made from a mixture of pure linseed oil and whiting, to which one-tenth part of white-lead putty has been added. A liberal number of triangular zinc points should be used. Before the glass is set the sash bars should be painted with a linseed-oil paint so that the wood will not absorb the oil of the putty. If these directions are followed the putty will harden and cling tightly both to the glass and the wood and will last as long as the sash itself. Cheap commercial putty is sometimes made from marble dust and kerosene; this putty tends to curl away from the glass and fall off, thus permitting the rain water to lodge on the sash bars and rot them. Attention to details of glazing will greatly reduce the number of vexing window troubles.

NUMBER OF PANES IN SASH.

Sashes with six or eight panes of glass have been used to a large extent in the past in miners' houses. These permit the use of "single-thick" glass and reduce the expense of replacing broken panes. They do, however, catch more dirt, are more difficult to clean, and obstruct the light more than windows with larger panes. The leakage of air is probably greater and cracked or broken panes are apt to remain unrepaired longer than with larger lights. A two-light sash makes a very desirable window for a dwelling.

EASILY OPERATED WINDOWS.

All windows should be double sash and each sash should slide up and down with such ease that a child can operate it. Opening a window that binds is very trying and the occupant may neglect to admit fresh air to a room if the windows are in such a condition that it requires a bar to open them and a prop to keep them open. Windows often bind on account of the settling of a house and remedies for this are discussed under the subject of "Foundations." Windows often become loose, rattle, and leak because of shrinkage. After a new house has been in use for some time all of the windows should be carefully gone over and these defects remedied.

The windows should be weighted so that both sashes can be raised or lowered to any desired height. Sash lifts should be applied to the bottom rail of the lower sash to afford a hold for the fingers in raising the sash. In old houses in which weight boxes have not been provided, side sash locks should be installed. These are attached to the side of the window and will hold the window open at any desired height. They are cheap, costing only 50 cents or a dollar a dozen.

BLINDS NOT NECESSARY.

Outside blinds, or shutters, are unnecessary for a miner's house. They are apt to get out of repair quickly. The frame may sag and get out of shape, the slats may drop out or get stuck. The fasteners may become broken or bent. Frequently the blind is then tied back with a string and is then seldom used for the purpose intended, or is permitted to become a plaything of the winds and slam back and forth, breaking glass and causing other damage.

SCREENING WINDOWS.

Flies and mosquitoes are undesirable, not only because they are nuisances, but because they spread disease. In mining towns the fly evil is especially menacing because of the open privies and other insanitary conditions that frequently exist. These bad conditions should be uprooted at the source, but as an additional safeguard fly screens are urgently advocated. Unfortunately, many of the framed screens on the market are ineffective and expensive. Cloth netting, when tacked on the outside casing, makes an effective screen when in good condition, and on account of its cheapness may be renewed each summer. It is objectionable, however, because it is quickly torn or rotted. In communities where fly and mosquito disseminated diseases are prevalent many companies have encouraged the use of screens by selling them to the tenants at cost. Copper screening will perhaps prove cheapest in the end. It should have about 16 meshes to the inch.

DOORS.

DOORS AS INSTRUMENTS OF VENTILATION AND ILLUMINATION.

The illumination and ventilation of the house may be greatly improved by properly placing the doors. Advantage should be taken of these uses for doors in addition to their use as a means of entrance and exit. Frequently dark ends of rooms may be lighted by a glass-paneled door, ground glass being used where privacy is necessary. If the front door leads into a dark hallway the glass panel is almost essential.

Outside door frames should be recessed for attaching screen doors. Storm doors, of the same size as the screen doors, should be provided in cold climates for exterior doors which open directly into a living room. For a hall or vestibule the storm door is not so important. If the doors were stored in a company building when not in use, and were hung each season by a company carpenter, they would last much longer. This service would show the interest of the company in the comfort of its employees without carrying with it any semblance of paternalism.

The movement of air through the house can often be improved, thereby making the house much cooler in summer, by properly placing the doors relative to one another and to the windows. The use of transoms is advocated for the same reason. The transom may be used to advantage, especially in those bedrooms which have only one side exposed. Otherwise, when the door of such a room is closed at night, the room approximates a "hole in the wall," with such a slight movement of air that a comfortable and refreshing night's rest is impossible. A transom over the kitchen door will greatly help to remove the smoke incident to cooking and make the room more livable.

LOCATION OF DOORS.

The position of the furniture should be considered; the wall space can generally be used to better advantage in respect to this if the doors are placed near the ends rather than in the center of a wall. In a dwelling the outside doors usually swing in, and provision should always be made on the door frame for a screen door. In hanging interior doors the side on which the hinges are placed and the room into which the door swings may vary with circumstances; it is not necessary to follow one system. Doors should not swing so that when left open the lighting from a window is blocked or the opening of another door is interfered with. Such a conflict often occurs with closet doors, and should be guarded against. Sometimes it may be of advantage not to hang the door.

HANGING THE DOOR.

Great care should be used in setting the door frame, for if this is out of plumb the door will not hang well. Some woods swell in damp weather and contract in hot weather, and continue to do this season after season, so that if the door should be planed off to fit in one season it will be too small to stay closed in the other. For this reason pine doors are best for common use, as pine shrinks less than most other woods, and when once dried has little tendency to absorb moisture again.

Strong hinges firmly secured with long screws should be used. All the hardware should be of plain design for ease in cleaning and for durability.

Stock doors are made 1⅛ inches, 1⅜ inches, and 1¾ inches thick. The 1⅛-inch door may be used for closets, but all other interior doors should be 1⅜ inches thick. Outside doors should be 1¾ inches thick. Stock doors usually vary between 2 and 3 feet in width and from 6 feet 6 inches to 7 feet in height.

CEILING VENTILATORS AND LOUVERS.

In addition to windows, doors, and transoms, ceiling ventilators and louvers are a help to ventilation. If the ventilator is placed in a closet, the ventilation can be controlled by opening or closing the closet door. An additional advantage is that the closet and clothes therein are kept fresh and wholesome. Openings in the ceiling are of no benefit as a means of ventilation unless louvers are placed in the eaves of the cottage. (See Pl. VIII.)

ARTIFICIAL ILLUMINATION.

In the artificial lighting of miners' cottages it is important to use a system that gives a well-diffused light, does not vitiate the atmosphere, and does not increase the fire hazard.

It has been estimated that an ordinary gas jet will consume as much air as two people and that a kerosene lamp will use as much as four people. When to these disadvantages are added the danger of leaking gas and the menace of the oil lamp in the presence of children, it is hoped that these methods will be abandoned.

In many mining towns the houses are lighted by electricity, and this system should be universally adopted. Electric bulbs do not vitiate the atmosphere, and if the house wiring is properly done there is practically no danger from fire. Note position of electric lights shown in Plate VI.

FIREPLACES, STOVES, CHIMNEYS, AND FLUES.

WARMTH NECESSARY AS WELL AS AIR AND LIGHT.

In discussing the means of obtaining an abundance of air and light, the question of the warmth of the house forthwith intruded itself. Unfortunately, fresh air during certain seasons of the year is also cold air, and some artificial means must be adopted for warming it. It is believed by many that breathing the artificially heated, stale air of the house is responsible for many of the ills that afflict humanity, and the tendency seems to be to revert to the out-of-door life. This can be done conveniently during one's sleeping hours by means of a window tent, if a sleeping porch is not practical.

If care is used in the erection of a house, the problem of keeping the house warm will be greatly simplified; and throughout this paper emphasis is placed upon construction details for this reason.

FURNACES.

Few miners' houses have individual furnaces. Although no one will deny that this system is very convenient, it is felt that there are numerous more important improvements calling for attention. On account of the smallness of the miner's house, the necessity of building a cellar demanded by this arrangement, and the consequent increase in rent, the universal installation of such systems is not recommended.

FIREPLACES.

Fireplaces and stoves are the two methods usually adopted for heating the small cottages in mining towns. The fireplace is not as efficient as the stove for keeping the room at an even temperature, but it is valuable as a ventilating apparatus, as it removes the impure air and constantly renews the air in the room by suction through cracks in the walls and around the doors and windows.

A stout screen should be provided for the fireplace to prevent sparks flying into the room and to prevent accidental burns from the open fire. Children particularly are subject to such accidents.

CONSTRUCTION AROUND CHIMNEY.

If the chimney breast over the fireplace or mantel is to be furred out and finished with lath and plaster, only metal lath should be used. If the mantel is to be of wood, it should not project far enough to be blistered or ignited.

All floor timbers should be trimmed clear of the brickwork of the hearths and chimney, so as not to be in contact with it at any point. This is secured by header beams, carried in front of the fireplace and at least 20 inches from the chimney breast, supported by the trimmer beams, which enter the wall on each side of the chimney. These should not approach the side of the chimney closer than 4 inches. The intervening tail beams, as they are called, are mortised into the header. In this way the floor beams are free of contact with chimney flues. (See fig. 6.)

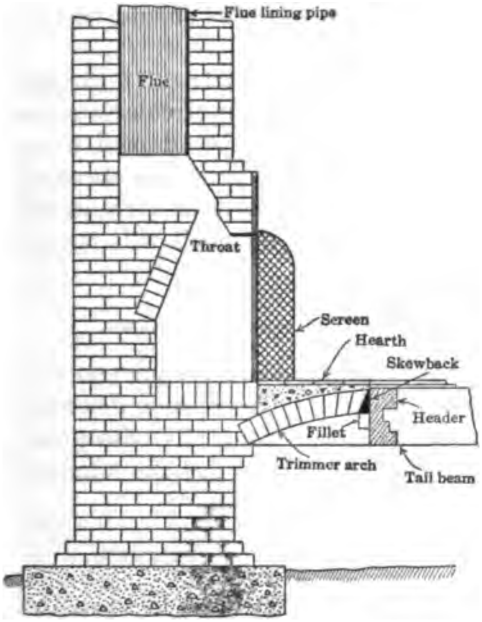

FIGURE 6.—Cross section of chimney, showing construction.

HEARTHS.

All hearths should preferably be laid on trimmer arches of brick or a reinforced concrete slab extending from the chimney breast to the header beam already described, so that the hearth shall not rest upon or near wooden beams in any case. The length of trimmer arches should not be less than the width of the chimney breasts, nor their width less than 20 inches, measured from the face of the chimney breast. (See fig. 6.)

STOVES.

The most effective place for a stove is near the cold or exposed side of the room, possibly between two windows, so that the chill may be removed from the cold air as it enters the room. This is on the same principle that radiators are placed underneath the windows. The position of the chimney should be selected with this thought in mind, unless it is to be used by the stoves in two different rooms, in which case it must be in the partition between the rooms. The more efficient heating would hardly warrant the cost of an additional chimney.

It is desirable to have a short stove pipe, so the stove should be near the chimney. The stove should be placed far enough from the wall so that there is no possibility of blistering the paint, and a piece of sheet tin or galvanized iron should be provided for the stove to rest upon.

When a stove is used, the windows should be lowered slightly to insure an adequate supply of air.

The department of public instruction of the commonwealth of Virginia describes in one of its recent circulars[a] a method of heating country school rooms which might be adapted to cottages. It suggests that a ventilator be placed under the stove to permit the entrance of fresh air and that the stove be surrounded with a galvanized-iron or tin jacket so that the chill will be removed from the incoming fresh air.

CENTRAL HEATING PLANT.

In some instances it might prove economical to heat the houses from a central heating plant. This system deserves to be carefully studied, the important factors being the cheapness of power, the nearness of the houses to the plant, and the number of months during the year that heat is required.

CONSTRUCTION OF CHIMNEYS.

CHIMNEY FLUES.[b]

A chimney should not be built with the idea of using it as a heating device; to do so is dangerous, but should be so built as to conduct the smoke and heated gases directly into the open air. Defective flues are among the most frequent causes of fire.

All chimneys should be built from the ground up, and the foundations should extend below the frost line. The practice of supporting chimneys or flues on floor beams or wooden or iron brackets is hazardous. A small fire around the base may drop the flue and allow draft for the rapid spread of fire.

HEIGHT OF CHIMNEY.

All chimneys should be built to a point at least 3 feet above flat roofs and 2 feet above the ridge of gable roofs. Down drafts are frequently caused in chimneys in the L's of buildings, because the chimneys are not built sufficiently high. Air in motion has the peculiarity of clinging to surfaces over which it passes, and in following down the pitch of a roof, if the chimney flue is in the descending current, a down draft will be caused. Often down drafts may be prevented by covering the top of the chimney with a semicylindrical cap of brick, or similar device, having its axis at right angles with the direction of the downward current so that the chimney gases can issue from the ends of the cap.

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[a] Form X, No. 45.

[b] Most of the following recommendations have been adopted from a bulletin issued by the National Fire Protection Association.

SECTION THROUGH CHIMNEY.

A chimney should not be built with a wall less than 8 inches (two courses of brick) thick and cement mortar should be used up to the first floor and above the roof line. The walls of the chimney, from 12 inches above the roof to the top, may be only 4 inches thick if the bricks are carefully bonded together with cement or fireproof mortar. All chimneys should be large enough to give a separate flue for each fire, using fire-clay or terra-cotta linings at least 1 inch thick. Two connections to a single flue may result in fire from one connection communicating to the opening of the other, and thousands of fires are said to have originated in this manner. Where flue linings are not provided all joints on the inside should be struck smooth and projections of brick or mortar should not be allowed, nor should the inside of the flue be plastered.

INTERIOR AND EXTERIOR FINISH.

FLOORS.

Emphasis is laid on the necessity of making the floors of plastered houses less vibrant than was the practice when the houses were ceiled with wood. A number of companies are now plastering their houses, and unless the floor is well braced the plastering will crack, and an excellent sanitary improvement will be unjustly discredited. The floor joists should be spaced sufficiently close and should be stiffened by bridging to prevent vibration.

A house with cold floors is especially uncomfortable. It is earnestly recommended that the floors of all miners' houses be made of two layers of boards, and it is a good plan to place heavy paper between the layers. The lower layer may be made of rough boards of irregular width and three-fourths to seven-eighths of an inch thick, laid diagonally. The upper layer should be made of narrow boards, preferably matched, one-half to five-eighths of an inch thick, laid perpendicularly to the floor joists and blind-nailed to the joists only. If the two were laid in the same direction, the shrinkage of the wide boards underneath would tend to pull two or three of the narrow finished boards together, thereby leaving open joints, corresponding roughly to the widths of the boards below.

The matched floor should be given a coat of filler paint and a finishing coat of floor stain or of varnish. If the floor is to be painted, the paint should contain a large proportion of hard oleoresinous varnish and should be heavily charged with dryer. Numerous hard, quick-drying paints, especially adapted for floors, are on the market. With a view to discouraging the nailing of carpets to the floor, which is an insanitary arrangement and is not necessary if the house be warmly built, a border should be painted around the edges of the floor.

PLASTERING.

Plastered houses are being built in a number of the new mining towns. Plaster makes a warm, clean, interior finish and is said to be less expensive than ceiling with wood. As a plastered house is warmer than one ceiled with wood, greater window area may be allowed and the house made more lightsome. If plaster is used. consistent construction should be followed in other respects. Attention is again called to the necessity of good foundations and rigid floors; otherwise big sheets of plaster may fall off and expensive repairs and unsightly walls result. Good material should be used and the laths should be laid one-fourth to three-eighths of an inch apart, so that the plaster will form a good clinch on the back of the laths. The laths on a wall should all be laid in the same direction; the shrinkage of laths that are placed at right angles to one another often causes plaster to crack.

PLASTER BOARDS.

Plaster boards of various compositions are used in place of lath and plaster. This construction is said to be cheaper, more resistant to fire, and to furnish better protection against extremes in weather.

PAPERING.

Although wall paper at first may furnish an artistic charm, it soon fades, becomes dirty, and gets torn, and makes anything but a pleasing appearance. Perhaps the danger of arsenic poisoning from the green coloring matter in wall paper has been overexaggerated, but this and other coloring may give off odors which are unpleasant if not dangerous. The flour paste which is used in hanging the paper will slowly putrefy, which helps to cause the musty smell characteristic of houses that have been closed for some time. This flour paste also furnishes food for vermin, and when these get concealed under the paper it is difficult to destroy them. With a view to preventing this, an insecticidal solution is sometimes mixed with the paste. The fibrous pores of the wall paper may harbor germs if the house has been occupied by a person suffering from a contagious disease. Because of the expense of removing old paper when a room is repapered, the dirty, greasy paper is often covered over with the new paper, and this, of course, intensifies the evils heretofore mentioned.

If wall paper is to be used, a good way to insure proper hanging of the paper, one practiced by several companies, is to have the tenant furnish the paper and to have a representative of the company hang it. This is much better than the reverse arrangement, which is adopted at some places.

INTERIOR PAINTING AND KALSOMINING.

The substitutes for wall paper are painting, kalsomining, and tinting. New plaster does not take paint well, because of its alkaline character, and newly plastered walls are best allowed to remain unpainted for at least a year. Various and attractive tints may be applied whose charm and interest last much longer than many of the gaudy designs seen in cheap wall paper. Oftentimes figures may be stenciled around the border, which will improve appearance and add contrast.

INTERIOR WOODWORK.

All the interior woodwork, as baseboards, window and door frames, moldings, and stair rails, should be plain and without such ornamentation as flutings, ogee curves, beadings, and filigree designs. None of the woodwork should be installed until the plaster has dried. It is best to keep the woodwork out of the house while plastering, so that it will not absorb the moisture given off by the plaster. The ledges should be beveled and the intersections between floors and walls should be filleted with a triangular piece, instead of the quarter round that is used so extensively. Picture molding should not be used, but knobs should be screwed into the walls at places where pictures might be hung to good advantage. Attention to these little details will reduce the number of dust pockets and crevices, which are difficult to clean, and will lessen rather than increase the cost of the house.

MODEL FURNISHED HOUSE.

It is not desirable for the company to dictate the methods of furnishing houses. Even if conditions are not up to the desired standard of sanitary perfection the evils arising from interfering in the home might incur graver consequences. It is none the less true that some discreet method of showing good and bad interior arrangements would cause desirable information to be diffused in the mining town. Such information reaches the miner's house slowly unless special efforts are made to disseminate it. The isolation and homogeneity of a mining population, the great number of non-English-speaking people, their recent advent into this country, the absence of libraries and lectures, and the scarcity of newspapers and magazines make some such effort desirable.

On this account, in addition to the regular educational channels, as the schools, some companies have employed visiting nurses and social workers whose duties are to render assistance along such lines as furnishing the house, cooking, modern methods of taking care of the baby, etc. In addition to special training and experience, great tact must be exercised by the person or persons employed in this work if permanent good is to be accomplished.

One progressive company has successfully and tactfully met this problem by setting aside a cottage and furnishing it in a clean, modest, up-to-date manner and throwing it open to the public for exhibition. The cost of each piece of furniture is plainly marked and the total cost of furnishing each room is conspicuously printed on a placard. This feature also thwarted another local evil, namely, the imposition of unscrupulous furniture dealers who sold furniture on the installment plan at exorbitant prices.

The educational feature of the exhibition house might be carried further to advantage. A placard on the bedstead might call attention to the position of the bed relative to the windows, another may explain that an iron bedstead is not broken so easily as a wooden one, affords better ventilation, and is more easily kept free of vermin. Attention should be called to the bedclothes and to the advantage of sleeping between sheets in order that heavy blankets will not have to be washed so frequently. The sleeping room should be free from unnecessary furniture, pictures, trinkets, drapings, canopies around the bed, fancy table coverings whereby a lamp might be upset by a child, mantel decorations, etc. There should be no carpet nailed on the floor and the windows should not have lace draperies. An appropriate placard could state that lace curtains, carpets, and draperies offer collecting places for dust and germs and make the living rooms less healthful. The windows should be screened, and the necessity of opening the window from the top and bottom should be suggested.

The above suggestions will serve to indicate how inroads may be made into local customs or fetishes without causing friction.

THE VERANDA.

IMPORTANCE OF THE VERANDA.

One of the most important health features of a house is the veranda. It is sometimes called a piazza, a porch, or a gallery, and is an invaluable asset in seasonable weather. No house should ever be built without at least one veranda. The veranda also serves to add beauty and variety to the house.

FOUNDATIONS OF VERANDA.

The foundations of the veranda should be strong and stable. If piers are used they should be inclosed by latticework, especially those of the front veranda. A variety of designs may be used on the latticework; broad horizontal bars reduce the "up in the air" appearance of a high veranda, and vertical bars relieve the "squattiness" of a low one.

FLOOR OF VERANDA.

The veranda, especially the one in the rear, should be built with the thought that it is frequently to be used as a playroom for children and as an airing place for babies. It should be so arranged that the child can be left with safety while the mother performs the household duties. Sometimes the floor of the veranda is laid with a ¼-inch crack between the boards, chiefly for the purpose of shedding water. Such a floor is uncomfortable to walk upon, especially for children with bare feet, and money or trinkets may be dropped through the cracks. A better method is to put in a tight floor with a pitch of one-fourth inch per foot. The boards of the floor should be laid perpendicular to the side of the house so that if they warp up at the edges the channels formed will be in the direction of the flow. The floor should be made of quarter-sawed wood so that it will not sliver. The level of the veranda floor should be a few inches below the level of the main floors of the house.

BALUSTRADE OF VERANDA.

The railing or balustrade should be designed with a view to simplicity, safety, and, above all, durability. It must be kept in mind that the balustrade may be frequently used as a footrest or seat. The top and bottom rails should be beveled to shed water and the bottom rail should be a few inches above the floor. Frail, fancy-turned vertical pieces should not be used; plain rectangular pieces, closely spaced, are better. If the floor of a front veranda is near the ground the balustrade may be omitted if the yard has a front fence, but if the front fence is omitted (see "Fences") the balustrade adds a needed touch of privacy. A pleasing and inexpensive column may be built by using two 2-inch by 4-inch scantlings separated a few inches and interlaced with narrow strips. The scantling should be dressed on all sides and the sharp corners chamfered.

VERANDAS WITH AND WITHOUT ROOFS.

At times it may prove advisable to omit the roof of the veranda, as this is frequently the cause of dark, sunless rooms. Frequently kitchens have only one side exposed, and if the windows on this side are shadowed by the veranda roof that much-used room is made cheerless. If the veranda is on the north side of the house the roof might be omitted with advantage or if the house has two verandas the roof might be omitted from one. It is undesirable to darken the verandas with vines, but the use of flower boxes should be encouraged. If the roof of the veranda is built flat or with a slight pitch, it may be developed into an out-of-door sleeping porch by the tenant. It appears an unnecessary expenditure to box in underneath the veranda roof; this makes a more finished interior appearance, but does not add to the general appearance of the veranda. This boxed-in space slightly increases the fire hazard.

"BUILT-ON" VERSUS "BUILT-IN" VERANDAS.

The "built-in" veranda should seldom be used on miners' houses, because of its expensiveness. This type of veranda robs the interior rooms of valuable space and is not so open, well ventilated, or breezy, and does not furnish such a variety of outlook as does the "built-on" veranda.

VERANDA STEPS.

The steps are a part of the miner's house that are frequently out of repair. This is generally due to cheap and thoughtless construction, and not to abuse. Although the steps are not designed as cantilevers, they frequently become such in usage by the washing away of ground support. The part of the steps in contact with the ground should rest on a permanent, unmovable, substantial foundation. The stringers should be of 2-inch stock, spaced about 16 or 20 inches apart. The treads should be made of 1⅛-inch stock, and should be slightly pitched to shed rain. The risers should be made of ⅞-inch stock, but should always be boarded up for safety. The appearance of the steps is improved by latticing the sides.

The angle of the flight of steps often depends upon the height of the veranda, but should never be steeper than 45°. The following rules are frequently used: The sum of the rise and run should be equal to 17 to 17½ inches. The sum of twice the rise plus the run should not be less than 24 nor more than 25 inches—for example, 7½-inch rise and 10-inch tread. The product of the rise and run should not be less than 70 nor more than 75. Handrails should always be added on high, steep steps. When it only requires one or two steps to mount, these can be advantageously made from concrete.

As formerly stated, appearances can at times be improved by having front steps sidewise to rather than facing the street, and at times a combination of both directions may be used to advantage, particularly on verandas that are rather high. It is economical to have the steps of a front veranda lead up from the footwalk, which runs from the front to the back of the house. This does away with the necessity of two front gates and the front footwalk, and does not cut up the front yard. The indirectness of the approach by having the steps at the side (see fig. 4) is of small consequence.

OUTSIDE PAINTING.

One of the predominant characteristics of mining towns has been the sameness of all the houses, which has been largely caused by the houses being painted the same color. The appearance of a town is greatly improved by various combinations of harmonious colors.

It is claimed that more durable results are obtained when tinted rather than white paints are applied. "Permanent coloring materials which have been ground by machine into a high-grade white-paint base have the effect of preventing 'chalking' and 'checking,' two defects that are often observed when white paints are used."[a]

In painting new houses the priming coat should contain a large proportion of oil, since much oil is absorbed by the new wood. It is considered good practice to add about a half gallon of raw linseed oil to every gallon of paint used as a priming coat. This makes the paint for priming cheaper and better adapted for its purpose.

Very often blisters form in paint applied over woodwork which has not thoroughly dried. As the paint film is comparatively impervious, the water underneath, not being able to escape, expands and forms a blister. To avoid blistering it is recommended by some to apply only two coats of paint to a new house. The thinness of the two coats will allow the moisture to evaporate, and when the house is a few years old and thoroughly dried a third coat may be added with good effect. Better results are claimed for this method than by adding the three coats at one time.

USE OF CREOSOTE STAINS.

Creosote stains are being used to a large extent as a substitute for paint. Creosote has numerous advantages. It is cheaper, both in cost of material and cost of application; it permits the evaporation of moisture contained in the wood and has valuable preserving qualities. Paint may be added after the wood has been stained with creosote, if later a greater variety in color is desired.

FOUNDATIONS.

TYPES OF FOUNDATIONS.

The foundation of the house will be discussed both as regards healthfulness and stability. The heated house acts like a chimney and much of the air that enters the rooms is sucked up from the cellar. It is consequently important to see that this air is not vitiated, or the value of other ventilating precautions is greatly lessened.

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[a] Institute of Industrial Research, Circular 2, December, 1911.

The air that comes up from under the house may be a combination of atmospheric air and ground air, the relative quantities of each depending to some extent upon the type of foundation. The amount of ground air entering the rooms is larger in houses having unventilated cellars without cement floors than in houses resting on piers. However, unless the openings between the piers are inclosed with boards, local nuisances may arise which will cause the air to become foul before it enters the rooms. The effect of the closed foundations on the warmth and comfort of the house must be given proper consideration.

It is important to see that the space underneath the house is kept dry and free from dampness. If the soil is damp it will increase the moisture content of air entering the house and will promote disagreeable fungus growths.

GROUND AIR.

The ground air[a] is the atmospheric air that has penetrated into the interstices of the soil and has taken part in the various chemical changes in connection with vegetable growth and decay. When decay is going on the carbon dioxide content increases and the oxygen content decreases. Many of the views formerly held on the danger of breathing ground air per se are being changed. Breathing in small quantities the air affected by such natural changes may do no great harm; if, however, the ground immediately surrounding the house is polluted with kitchen slops and leachings from defective drains, choked cesspools, privy vaults, pigpens, and stables, aside from the direct dangers of infection, these conditions doubtless exercise an unwholesome influence on the air breathed.

ADVANTAGES OF FOUNDATION WALLS.

Walls or piers of masonry or timber posts may be used as foundations for the miner's house. Although the choice of these depends largely upon local conditions, the use of the wall in preference to posts is urgently advised. The wall is necessary for a masonry house and is essential in extremely cold climates, but even where these conditions do not apply, the foundation wall has many advantages.

Building a house on widely spaced, inadequately braced wooden posts or imperfectly laid masonry piers, which rest on cheaply improvised footings is false economy. Frost action, weathering, and surface washes weaken the supports; the house timbers settle and sag; leaking roofs, unclosable doors, and sticking windows result; patches and repairs are constantly needed; tenants are always complaining. Moreover, a greater number of plastered houses are being erected now than formerly, because they are warm, cheap, and clean. These require a much better support than the old type wooden-ceiled house, as a settling that can occur with impunity in the latter will cause expensive damages to the plastered house.

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[a] For discussion on significance of ground air, see Rohe, George H., and Robin, Albert, Textbook on hygiene, 1908, p. 161.

CONSTRUCTION OF WALLS.

Concrete, artificial stone, brick, terra cotta, and rubble may be used for walls, but usually concrete will be least expensive, especially where a large number of houses are to be erected.

On a level lot a wall is not an expensive foundation. If the drainage of the town site has been improved there is no necessity of having the walls 3 or 4 feet high merely to have the house " off the ground," a wall 12 inches above sidewalk level serves the purpose. It would be better to place the extra concrete below the surface, so that the bottom of the foundation will extend below the frost line. It is not necessary to have the entire wall extend below the frost line; columns every 8 or 10 feet are sufficient.

If care is taken with the subsurface wall the exposed part need not be more than 10 inches thick. Metal forms, which may be used over and over again, should be considered if much concrete is to be laid. The exposed part should have ventilating holes, the openings of which should not be large enough to permit entrance of rats. Cast-iron gratings are sold which serve the purpose, or narrow vertical slits may be left which do not require any grating and may also be effective as expansion joints. Before the floor system is laid all shrubs, chips, and trash should be removed from the inclosure. Walls permit the use of smaller sills and also do away with the necessity of diagonal bracing and of boarding up the inclosure.

SPECIAL WALLS.

On sloping lots a stepped foundation wall should be built. On a very steep hillside lot the ordinary masonry foundation wall is very expensive and it may be more economical not to use some lots for a dwelling. Under some circumstances it may be feasible to build a foundation wall consisting of concrete piers to carry the main load and have these connected by a thin curtain wall.

CELLAR.

A small cellar about 8 feet square should be excavated under the corner of the house. The cellar should be walled up and the entrance should be from the outside. Such a small basement makes a cool place to keep milk and butter, as ice is not available in most mining towns, and furnishes a storage place for vegetables for use during the winter.

PIERS.

In a warm climate, if a frame house is to be erected, piers that are properly designed and adequately spaced and braced make a satisfactory and economical foundation. Wooden, concrete, and brick piers are used, but the best pier requires a combination of these materials. In any pier the footing is the most important part. The footing should have a good bearing surface and be permanently fixed so that it is not affected by weathering, surface washing, or frost action. Brick laid in mortar does not make a satisfactory or economical footing; concrete is preferable. The material of the pier necessarily depends upon circumstances. In a low pier 10 or 12 inches high, a wooden post is not satisfactory, because of lightness and liability of splitting; masonry should be used. For a high foundation, brick or concrete piers are difficult to brace; wooden posts on a concrete footing are better. The footing should extend a few inches above the ground and be mixed wet and be puddled to a smooth surface to furnish a good bearing and to prevent water from collecting underneath the post. Plastering the footing with cement after the concrete has set is not effective.

NECESSITY OF CLOSING UP THE SPACE UNDERNEATH THE HOUSE.

If the openings between the piers are not boarded up experience has shown that this shelter will be used in ways injurious to health. Cows, hogs, geese, hens, dogs, cats, or rabbits may get under the house and fleas, vermin, and lice may gain entrance to the house in this way. In winter the warm house acts as a chimney and the unhealthful odors caused by these animals are sucked up into the rooms. The opportunity for children to play underneath the house should not be permitted, as the atmosphere there is impregnated with organic dust which may cause injury to the child's lungs. This space if accessible might be used as a storeroom for old broken furniture, which furnishes breeding places for vermin and increases the fire hazard. Leaving the foundation open exposes the floor to the winds and makes the house uncomfortable in cold winter months. The additional money spent in boarding up between the piers will be well invested.

FRAMEWORK.[a]

KNOCKED-DOWN HOUSES.

When a large number of houses is to be framed there may be economy in adopting a system of construction similar to that used in the erection of modern steel buildings. This means the standardization in the drafting room and the sawing, planing, and fitting by machinery in the shop of all of the heavy timbers, as sills, girders, posts, studs, joist studs, and rafters, marking each piece and distributing them at the proper lot for erection. There is a saving of labor because of the greater efficiency of power-driven machines over hand tools, and in instances where the company operates its own sawmills much material can be saved by cutting the logs the desired length. This system requires careful planning and intelligent supervision.

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[a] For detailed information on the construction of a house, see Cyclopedia of architecture, carpentry, and building, vol. 2, 1908, pp. 27–118; Kidder, F. E., Building construction and superintendence, pt. 2, 1899, pp. 46–106.

There are some house-building companies that carry the idea much further, not only cutting the heavy pieces to fit but also the sheathing, siding, molding, rails, steps, etc. These pieces are marked and the knocked-down houses shipped to any point in the United States.

TYPES OF FRAMES.

THE BRACED FRAME.

There are two types of frame houses; one is known as the "braced" frame and the other as the "balloon" frame. The braced frame is seldom used now on account of its expense, but a short description will be given, as some of its features might be adopted advantageously under certain circumstances. In this type the sills, posts, girders, and plate are all mortised and pinned together, and the posts are diagonally braced by heavy members, which are mortised and pinned. The studs are all mortised into the sill, girder, and plate. The strength of a braced frame is independent of the sheathing, and it is therefore less liable to become distorted than a balloon frame. The braced frame was used when lumber and labor were cheap and nails were expensive. The old colonial houses were of this type, which helps to explain their remarkable durability.

BALLOON FRAME.

The balloon frame is composed of lighter pieces and is more quickly erected. The main timbers are held together largely by spikes and the studs are simply nailed to the sill and extend from the sill to the plate, the girder being omitted. If the studs are not long enough they are spliced. In place of the girder a 1-inch by 7-inch board, called the false girder or ribbon, is nailed on the inside of the studs to support the second-floor joists. On each side of all door and window openings the studs should be doubled, and in two-story balloon-frame houses, where it is necessary for the studs to extend the full height of the wall, it is desirable to have the windows of the second story directly over those of the first. The balloon frame depends for its strength largely on the sheathing which binds the framework together, and for that reason the sheathing should be put on diagonally.

COMBINATION FRAME.

A combination of the above two methods is sometimes used. The braced frame is adopted as far as sills, posts, girders, and braces are concerned, but the studs are mortised at the lower ends and are only spiked at the upper ends. If the siding or clapboards are to be nailed directly to the studs (the sheathing being omitted), the method of framing is very important and a combination frame should be considered.

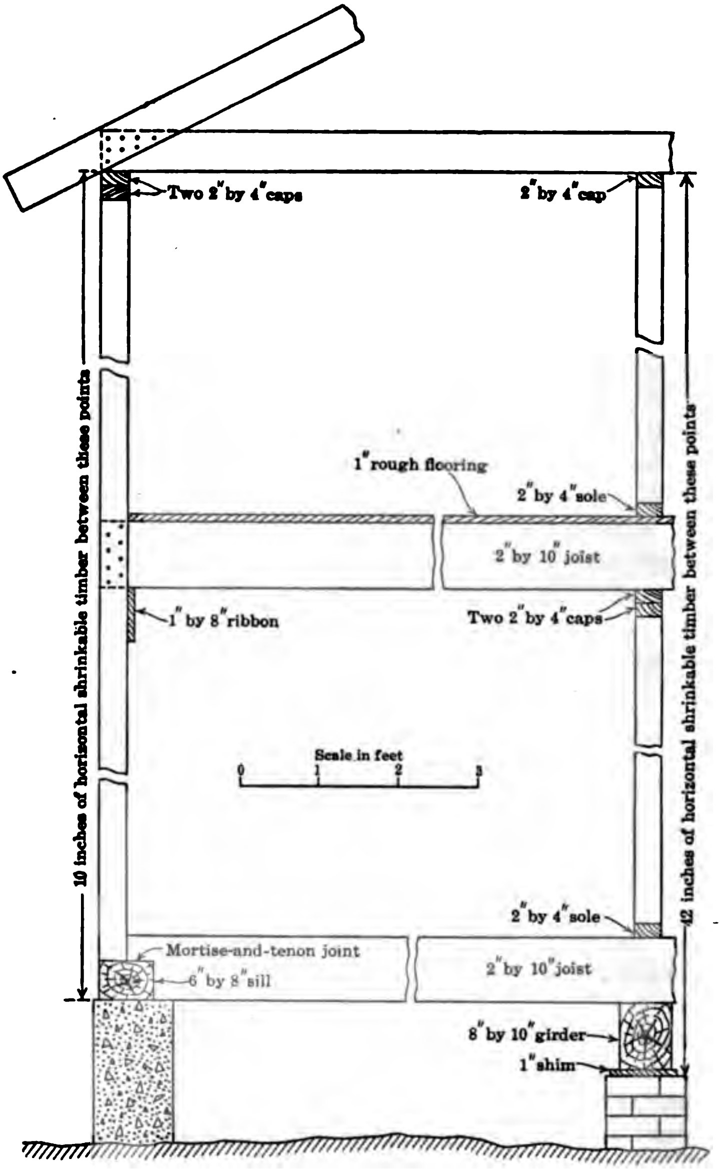


FIGURE 7.—Incorrect method of framing a house.

SHRINKAGE.

Under the subject of "Foundations" attention was called to the evils caused by the settling of the house, and remedial measures, in so far as the foundation was concerned, were suggested. Settling is also caused by the shrinkage of timbers, and, although this can not be avoided entirely, it may be minimized by using well-seasoned timber and by erecting the house in the warm, dry season.

The most practical remedy lies in controlling the shrinkage so that it is equally distributed. This can be easily done if certain simple principles are understood and enforced. The amount that timber shrinks along the grain is imperceptible and may be ignored. The chief shrinkage is across the grain, and in ordinary spruce or white pine this may amount to one-half inch for every foot of cross grain. It is therefore important to keep the amount of horizontal timber in the outside walls approximately the same as in the interior walls. Timbers placed vertically or on end do not contribute to the shrinkage, Figure 7 shows how the above practice is ignored and figure 8 shows how the settling due to the shrinkage may be appreciably reduced.

OTHER DETAILS.

The sill should be set in a bed of cement mortar and the bottom side should be painted with two coats of linseed-oil paint to prevent the timber from absorbing moisture from the foundation wall. The broad side of the sill should rest on the foundation wall, but the narrow side should face down, if piers are used. The sill should be set back an inch from the edge of the wall so that a water table (see fig. 8) may be built to shed the rain that drains down the side of the house.

Special attention is also called to the method of framing around a chimney, and under no consideration should any timbers come in contact with or rest upon the brickwork of the chimney. (See fig. 6.) The 2 by 4 inch piece inserted between the studs of a balloon frame on the outside wall at the second story is known as the "fire stop." (See fig. 8.) In case of fire it helps to prevent the fire from creeping from the bottom story or basement up between the partitions to the roof. It also helps to make the house more comfortable by preventing circulation of air between the partition walls.

THE ROOF.

ADVANTAGES OF GABLE ROOF.

When the roof slopes back from the ends of the building the same as at the sides it is called a hipped roof. The well-known gable roof and the hipped roof are the types most frequently used on small, inexpensive houses. In large houses the size of the span affects the type of roof selected. In approximately square houses the hipped roof is very popular. Although this roof requires less material (considering the saving of gable walls) than the gable type, it is questionable whether it is more economical. The labor on it is more expensive, because the rafters must be cut in many different lengths, and four or five ridges must be framed and flashed, as compared with the one of the gable roof. In case the attic space is ventilated.

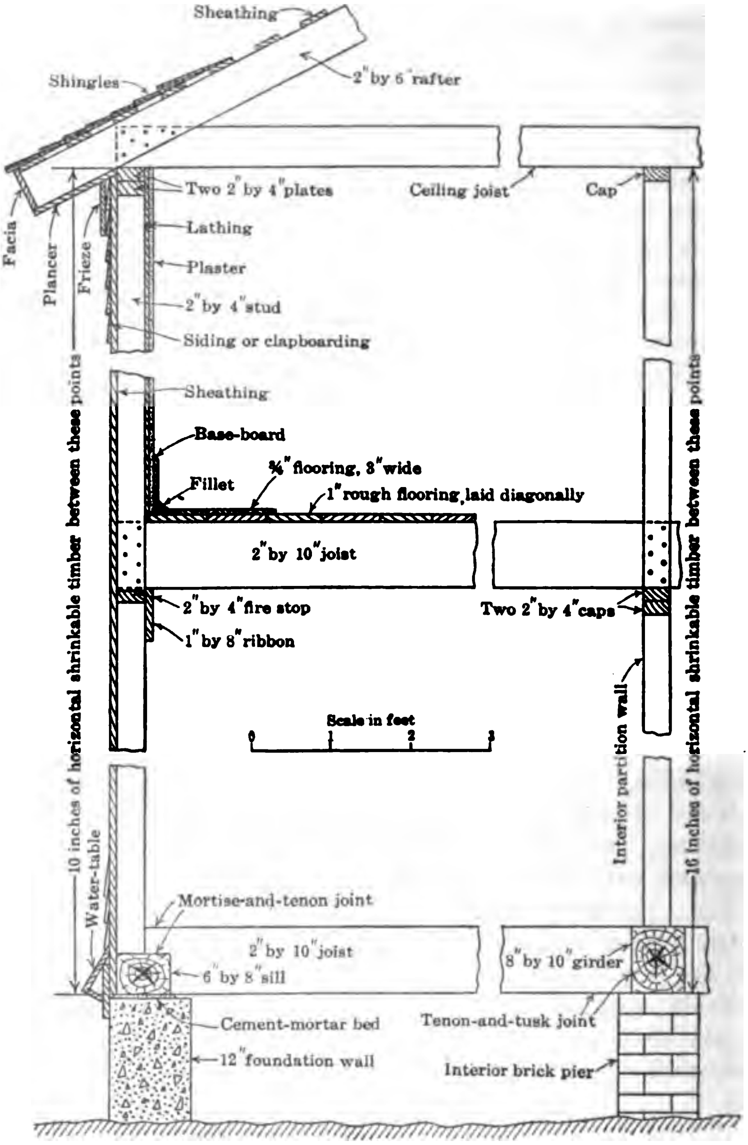


FIGURE 8.—Correct method of framing a house.

as it should be, dormer windows are necessary on the hipped roof, whereas a less expensive, plain window may be inserted in the gable ends of the gable roof. Another advantage of the gable roof is that the lineal feet of gutters, cornice, etc., is reduced one-half. Attention is called to the different effects that may be obtained by changing the direction of the ridge on a gable roof, and this resort may often improve the lighting of the adjoining houses.

NECESSITY OF A PLAIN ROOF.

The roof of the house is frequently used as a means of getting ornamental effects, but in this bulletin it is discussed chiefly as regards durability and incombustibility. A plain roof with just as few ridges and valleys as possible is advocated, because these increase the cost. and it is at the intersections that leaks frequently develop. Fancy trimmings on the ridges should be omitted.

FLASHINGS.

It is important that the ridges, valleys, and chimney should be carefully flashed. Tin perhaps makes the best and least expensive flashing material, but it should be painted on both sides. A good paint for this purpose is one made of red lead and linseed oil. The chimney should be surrounded by lead counterflashings in addition to the tin-apron flashing. Flashings on valleys are frequently cut too narrow, with the result that they overflow during heavy rains and the water works its way under the shingles and leaks result. On roofs having a pitch of 45° or more the flashing should be done with strips of tin at least 18 inches wide, and on roofs of less pitch it should be at least 20 inches wide. The end joints on flashings should be locked and soldered.

PITCH.

The pitch or slope of a roof depends largely upon the climate and the character of roofing material to be used. In a damp, cold locality steeper roofs are required than in a warm, dry, sunny one, because the high evaporation of the latter augments the pitch in drying the roof. The roof should not be too steep, but the pitch on a main roof should never be made less than one-fourth. which means that the rise is 3 inches to each 12 inches of span.

ROOFING MATERIALS.

Slate, wooden shingles, roofings composed of saturated papers or felts, finished with a coating of sand, crushed slate, or ground mica, and sheet metals are used for roofing inexpensive houses. The merits of these will not be discussed in full, but certain salient features will be touched upon.

SLATE.

Slate makes a durable fireproof roof, and in Pennsylvania, where slate is comparatively cheap, has been used to a considerable extent for miners' cottages. Its first cost is higher and it requires heavy supporting members, and an 8-inch rise in 12 inches is the least pitch recommended. If slate is used the roof should be simple to the extreme in order that the cost may be reduced. An asphalt-saturated sheet or a good grade of tar paper should be laid over sheathing boards before the slates are applied. In isolated houses, where a cistern must be used as a source of drinking-water supply, slate makes the cleanest watershed, but a mining town should not be dependent on cisterns for drinking water.

WOODEN SHINGLES.

Two methods are used in applying wooden shingles. One consists of completely boarding over the rafters and covering these boards with felt or paper before the shingles are laid. In the other method the shingles are nailed on narrow boards laid a few inches apart. The latter method is by far the cheaper in first cost, and the shingles last longer because of the better ventilation underneath. This method should not, however, be used if the attic rooms are to be finished, as it makes these rooms cold in winter and uncomfortably warm during the summer months.

The untreated shingle roof is objectionable on account of its inflammability, and is condemned by insurance authorities and also by the National Fire Protection Association, which has issued a bulletin condemning this type of roof covering. As clearly shown in that bulletin, burning shingles may be carried great distances by the wind or draft of conflagration, and if they alight on other dry wooden shingles may start other fires. In this manner a dozen separate fires may be started over a radius of a mile or more while the original fire is still being fought. Statistics show that never a day passes but somewhere in the United States or Canada a shingle roof is set on fire by sparks from the chimney.

Notwithstanding its inflammability the shingled roof is desirable on account of its low cost, light weight, coolness, and attractive appearance. Recent experiments by H. A. Gardner, of the Institute of Industrial Research, demonstrate that when shingles are painted with a high-grade mineral paint the deposited film has the effect of smoothing down the fuzzy surface and the mineral constituents increase the fire-retardant properties of the shingle.

PREPARED-FELT ROOFINGS.

Saturated-felt ready roofings are numerous in variety and composition. It is difficult to determine the exact value and relative permanency of some of these products from appearance alone, and attention should be given to their durability in service. Roofings of this type are usually unattractive, and also introduce a certain fire hazard, particularly if the roofing be composed largely of vegetable fiber saturated with volatile compounds.

ASPHALT SHINGLES.

More recently there have appeared upon the market the so-called "asphalt shingles," which are made from roll roofing, cut up and applied in the form of shingles. The general use of such shingles, however, has been too limited as yet to warrant a definite opinion respecting their permanency or durability as a roof covering.

METAL ROOFINGS.

Sheet-metal roofings are available in various forms. That most generally used for houses is the tin roofing, which is more often used where the pitch of the roof is limited. For verandas tin roofing is almost exclusively used. In applying tin it is essential that the boards upon which it is laid present a smooth surface, and it is desirable to have them run from the eaves to the ridge, so that if any warping or shrinkage occurs the channels thus formed will be in the direction of the water flow. It is very desirable to apply between the sheathing and the tin a layer of heavy sheathing paper of good quality.

Another familiar form of metal roof is the corrugated, galvanized, or painted steel sheet, which, however, is not at all attractive as a roofing for houses.

Metal shingles and imitation Spanish tile are made from galvanized and tinned steel sheets, and these produce a more attractive effect than any other form of metal roofing.

The difficulty of protecting the average metal roof against corrosion is one that merits consideration. The various protective methods, such as tinning, galvanizing, and painting, particularly the latter, are only temporary expedients. A multiple system of safeguarding the metal sheets against corrosion consists in first covering the metal with an adhesive, nondrying, bituminous compound and embedding asbestos felts therein. Metal sheets thus protected are available in various forms and colors suitable for general roofing purposes. They are not, however, well adapted for the covering of flat or substantially flat surfaces, owing to the impossibility of soldering them together as is done with tinned metal sheets.

OTHER TYPES.

Other types of roof coverings are available, but are not generally suitable for the roofs of small houses—such as built-up tar and gravel roof, a method that is not applicable to sloping roofs, and terra-cotta tiles, which generally are too high in first cost, and are too heavy to be suitable for structures of this kind.

GUTTERS.

The advisability of putting house gutters on a miner's cottage depends upon whether the streets are paved and whether the yards are graded and improved with gardens, lawns, and footwalks; in other words, house gutters are a complement of a finished town.

The use of the gutter as a means of conveying water to a cistern is not here emphasized, because cisterns are accessories of isolated houses and should not be found in mining communities of the future. In addition to this use, however, house gutters help to keep the foundation dry and prevent the spattering of mud around the base of the house; they prevent the washing away of soil and permit the utilization of the belt surrounding the house for flower beds or lawns; they prevent the formation of stagnant pools of water and protect the footwalk from mud and ice. Gutters may be made of wood or galvanized iron, and the conductors or leader pipes should be corrugated rather than plain, in order to allow for expansion in case they should freeze, as they frequently do in cold climates. Gutters, conductors, and goosenecks increase the cost of the house and are expensive to keep in repair; many of their advantages are nullified unless there are street gutters or a sewer system to receive the water from the conductors. The installation of house gutters should be postponed until other conditions are brought up to a consistent standard. However a short length of gutter should be placed on the veranda over the steps to prevent dripping of water and formation of ice on the steps.

THE YARD AND ITS APPURTENANCES.

COAL HOUSE.

Few miners' houses have cellars, so that the coal must be stored somewhere in the yard. In places where there are no alleys or where the rear yard is not accessible to a wagon, the coal house or box is placed in the front yard to reduce the cost of delivering the coal. The sight of a coal box on the front property line is anything but pleasing, and is out of place in the modern mining town.

In some places the coal house and privy have been combined. There appears to be no objection to this and it lessens the cost and reduces the number of small buildings in the back yard. This combination idea has been carried further and the privies and coal houses of two adjoining houses have been placed under one roof (Pl. III, *B*), the building being on the division line between the lots. There is, perhaps, not sufficient privacy and independence to this arrangement to allow it to be universally recommended. If it is adopted the privies should be in the two extremities of the building, and it is better, perhaps, to have the entrance to the privy on the end of the building and not on the side that faces the house.

DOMESTIC ANIMALS IN MINING TOWNS.

The population of mining towns often consists of people who are experiencing a transitional era. Many of them have been accustomed to living on farms, and they often bring along with them customs and practices that give rise to insanitary conditions in a thickly settled community. Notable among these is the keeping of domestic animals.

Animals may be kept with impunity on a farm, where they receive proper attention and where everything is open and spacious, and where the aromas of the barnyard are carried away by the great movements of pure air which come sweeping across the open country. But the circumstances are entirely different when a horse and cow, hens, hogs, geese, goats, rabbits, pigeons, and dogs are crowded together on a city lot of 50 by 100 feet, and when similar conditions prevail on 20 adjacent lots. It should be remembered that not only must the yard contain the patched shacks and coops for all these animals but there must also be room for the privy, washhouse, coal shed, outside oven, woodpile, and clotheslines. Under these cramped conditions the odors from the animal offal, pigsty, privy, steaming manure heaps, chicken coops, kitchen slops, goose puddles, and soggy ground are confined, and if the settlement is in a sheltered valley, as is generally the case, a stagnant miasma will overhang the entire community. Added to this are such nuisances as lice, fleas, and other vermin, the noise, and the scratching and burrowing in the soil of the yard.

PREVENTION EASIER THAN CURE.

In a new mining town certain restrictions regarding domestic animals should be instituted at the very beginning, as abuses are prevented much easier than corrected. Often county or State regulations supply the needed restraints if they are enforced. It might be a good plan to incorporate some of these measures in the house lease which is signed by the tenants. The keeping of hogs, geese, and ducks should be absolutely prohibited within the city limits, as it requires too much time and money to prevent nuisances from arising, in spite of the much-talked-of scavenger trait of the hog. This recommendation is made in the full knowledge of the popular use of pork, the toothsomeness of roast duck, the deliciousness of a fresh goose egg, and the comfort of sleeping under a "goose-hair" tick. Unfortunately, the community good requires personal sacrifices.

Building permits for stables should be required, and no stable should be erected until a permit has been granted. This regulation should in no way prohibit the keeping of horses, as the miner oftentimes needs a horse to drive to and from work, especially if the town is at a distance from the plant. This measure, however, will furnish control over the location and type of building, and will furnish an opportunity of coming to an understanding about the disposal of the manure, which is very important if the fly nuisance is to be prevented.

The building of stables should be restricted to lots in the outskirts of the town, unless the lot is quite large.

In order to prevent cows from grazing in the alleys and streets, a fenced pasture should be provided by the company. Regulations about diseased horses and cows should be rigorously enforced.

Chickens should not be permitted to roam about the yard, but should be confined within a runway. The coop should be whitewashed at regular intervals.

GARDENS VERSUS DOMESTIC ANIMALS.

In attempting to abolish the keeping of domestic animals consideration must be given to other phases besides strict sanitation, chief among which is the effect of these animals in reducing the cost of living. It is also undoubtedly true that the simple pleasures derived from caring for animals in feeding, breeding them, and building coops or pens is a factor in the life of the miner that should not be disregarded.

One frictionless method of combating the practice of keeping domestic animals is to encourage the planting of gardens. The garden has a wide range of advantages. First and foremost, the products from the garden reduce the cost of living. Not only are fresh vegetables furnished during the season, but many of them may be preserved for use during the winter.

The garden is an indirect means of improving the order and cleanliness of the yard. Trash, rubbish, ash heaps, stagnant water, and disorder will automatically disappear with the advent of gardens.

The gardens furnish a pleasurable and profitable way of engaging the miner's unoccupied time. Spare hours and days in which there is no run at the mine can be spent to great advantage in a garden. There is a wholesome influence from the very contact with green growing things. The miner's family will likewise reap many advantages. Helping about the garden will keep the children out of mischief and teach them thrift and industry.

Raising a garden means the investment of labor in the premises on the part of the tenant, and in the absence of individual ownership creates an added attachment to the place which tends to offset the temptation of packing up and following vague rumors about steadier work, higher wages, thicker seams, etc.

A number of companies have gone to much trouble and expense to encourage the planting of gardens. One company plows the yard, furnishes manure gratis and seeds at cost, and at the end of the season awards valuable prizes for the most successful gardens. (Pl. IV). Once the garden habit is started it ought to become largely self-supporting.

The Department of Agriculture publishes bulletins describing suitable crops for special soil conditions, which will prove valuable to those who desire to initiate interest along these lines. A limited supply of these bulletins is printed for free distribution, and may be obtained by writing to the Secretary of Agriculture, Washington, D. C. An incomplete list of the bulletins is as follows:

Farmers' Bulletin 154, The home fruit garden, preparation and care.
Farmers' Bulletin 218, The school garden.
Farmers' Bulletin 220, Tomatoes.
Farmers' Bulletin 255, The home vegetable garden.
Farmers' Bulletin 289, Beans.
Farmers' Bulletin 324, Sweet potatoes.
Farmers' Bulletin 354, Onion culture.
Farmers' Bulletin 407, The potato as a truck crop.
Farmers' Bulletin 433, Cabbage.

Several States have schools, experiment stations, and departments of agriculture, and by getting in touch with these information of particular local value may be obtained. The operators' associations might collect information from these various sources and distribute it among the workers. This practice has been adopted with marked success by the Alabama Coal Operators' Association.

FENCES.

The fences surrounding the houses in a company-controlled mining town have more significance than is usually attributed to them. If the amount of money involved be considered, perhaps no improvement sets in motion such a train of beneficial results as assigning, by means of a fence, a definite amount of land to each individual cottage. The fence fixes responsibility; it creates a healthy sense of pride and feeling of proprietorship; it insures a certain amount of privacy; it permits the planting of gardens and results in clean yards and premises. (Pl. I, *C*.) The painstaking, though unsightly fences, built by individuals, particularly among non-English-speaking people, display an inherent desire for the control of land, more or less dominant in us all. This trait should be gratified in the construction of new mining-towns, and in old towns a little money invested in neat fences will return good dividends.

Certain details of the fence discussed herein may appear far-fetched if only an individual house is concerned, but it should be remembered that if three or four hundred houses with large-sized yards are to be fenced every foot of lumber saved counts up. The fence should harmonize with its surroundings; but in this, as in other improvements, economical methods and simplicity of design and construction should govern.

LOCATION OF FENCE.

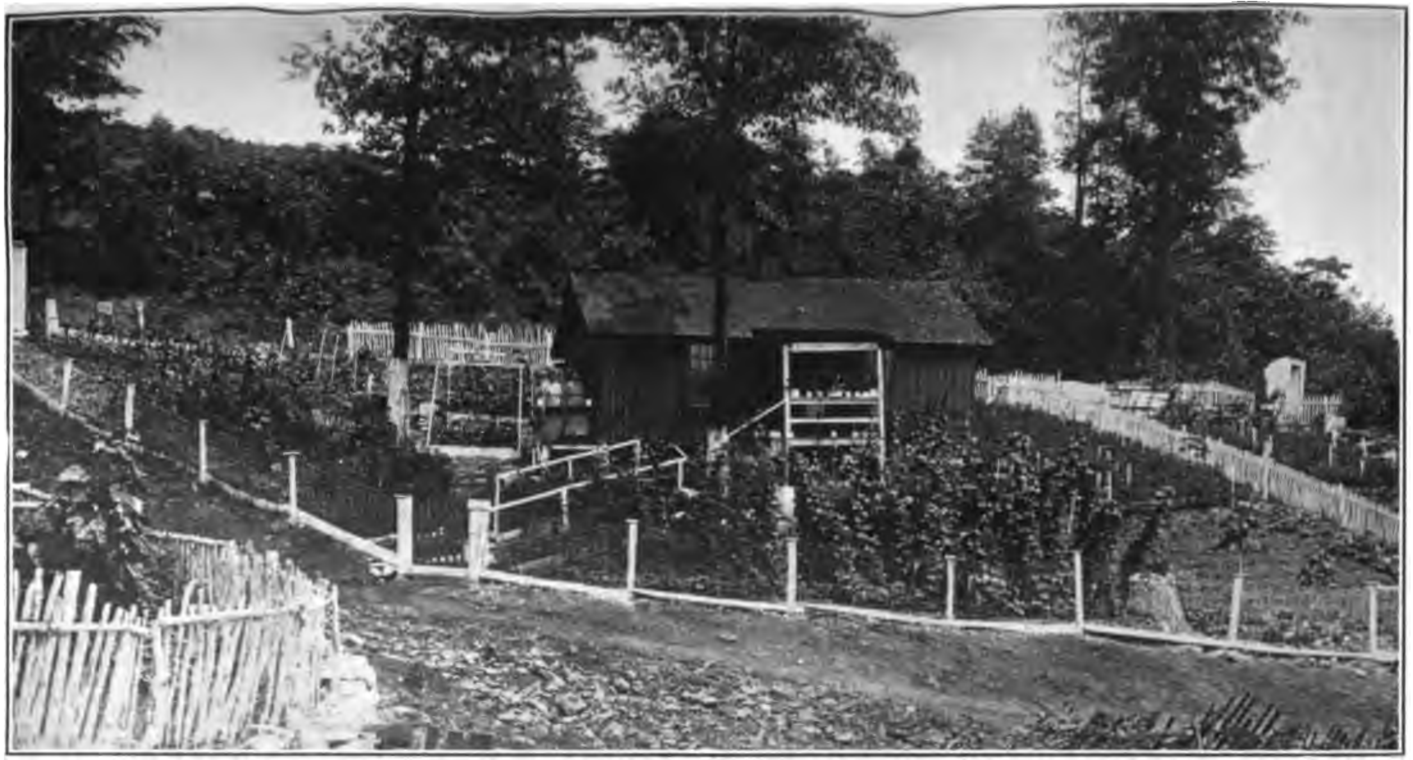
A pleasing effect may be obtained in some cases by setting the front fence back between the houses rather than on the front property line. By this arrangement a parklike area is made between the sidewalk and the houses, which may be grassed and will appear more spacious than if cut up by fences. This method also reduces the linear feet of fence. Similarly, if the house is on the side line rather than centered on the lot, the two side yards will be combined into one and the linear feet of fence required to inclose the lot will be reduced by the depth of the house. (See fig. 4.)

HEIGHT OF FENCE.

Oftentimes a low fence answers the purpose as well as a high one and costs less. As far as preventing people from trespassing, it is in its symbolism more than as an actual barrier that the fence is effective. In some places the fence must be built so as to keep out hogs. Even if the keeping of hogs is not permitted in the town itself, there may be no law against stock running at large in the surrounding country, and the yards and gardens must be protected from the inroads of these "outsiders." Usually this can be corrected by legislation, but a better method is by rigidly enforcing sanitation and cleanliness within the town. This means frequently collecting and destroying the garbage, trash, and other wastes which attract the unwelcome visitors. Hogs, like flies, are attracted by filth.

TYPES OF FENCES.

There are three types of fences largely used in mining towns—the rail fence with certain modifications, the woven-wire fence of various designs, and the pale or picket fence. The rail fence can be made artistic and is usually built rather low. It is not a very effective barrier. Woven-wire fences are usually unnecessarily high and are not very pleasing in appearance. They are, perhaps, the



MINER'S PRIZE GARDEN NEAR WEYANOKE, W. VA.

most economical fence and most effective barrier. In some cases they do not last long when they are built near coke ovens, on account of gases in the air. Specially prepared wire might be obtained to resist this action. The pale or picket fence is the best appearing of the three. In the construction of a new town, pickets can be made very economically by utilizing waste ends and trimmings. A very satisfactory and economical arrangement is to make the front fence out of pickets and the side and rear fences from woven wire. (See fig. 4.)

POSTS.

The post is one of the least durable parts in a fence and fails chiefly by rotting near the ground where it is subject to alternate wet and dry conditions. Creosoting makes the post more resistant to decay, and if it is not practical to have the posts treated under pressure, simply applying a creosote paint will be of some value. By making the height of the fence 4 feet instead of 5, and setting the posts that much deeper, the fence will be strengthened. Corner posts and those to which the gates are hinged should be diagonally braced. It might pay to set all the posts in concrete, in which case the concrete should extend three or four inches above the ground so that the post will be protected at the point most liable to decay. Concrete and metal posts, both of the manufactured and home-made type, are sometimes seen. Old boiler tubes and discarded water pipe when cut and drilled and embedded in concrete make very stable posts. The pipes should be filled with sand and capped with concrete.

GATES.

The gate is a second weak part of the fence, and numerous methods have been improvised for making a strong, durable, self-closing gate. The gate should be made as light as is possible without impairing its strength. This can be accomplished by using light wood and not making the gate unnecessarily wide or high. Long, strong, galvanized, strap hinges should be used and should be attached with long screws driven directly into the framework or standards. The flimsy, haphazard way in which hinges are applied is responsible for many broken gates. How often are gates seen with hinges attached to the picket side of the gate so that some screws must be left out because the hole in the hinge is between the pickets. The patented self-closing cast-iron hinges are easily broken. Figure 9 shows how a gate may be made self-closing with ordinary strap hinges by putting the hinges off center a little. This arrangement detracts little from the appearance and does away with the use of springs and counterweights. This is the same principle used in self-closing mine doors. The gate should swing in.

WATER AND WASTES.

The problems of water supply and disposal of sewage in mining towns are briefly discussed in the following chapter. These important sanitary factors will later be discussed more fully in special publications.

RESPONSIBILITY FOR WATER SUPPLY.

If an epidemic breaks out in a municipality whose citizens through ignorance or willingness to "take a chance" elect to drink polluted water, they are the unfortunate victims of their own shortcomings; but in a company-controlled town conditions are different, and the furnishing of safe, wholesome water is one of the gravest responsibilities accompanying this system of town control.

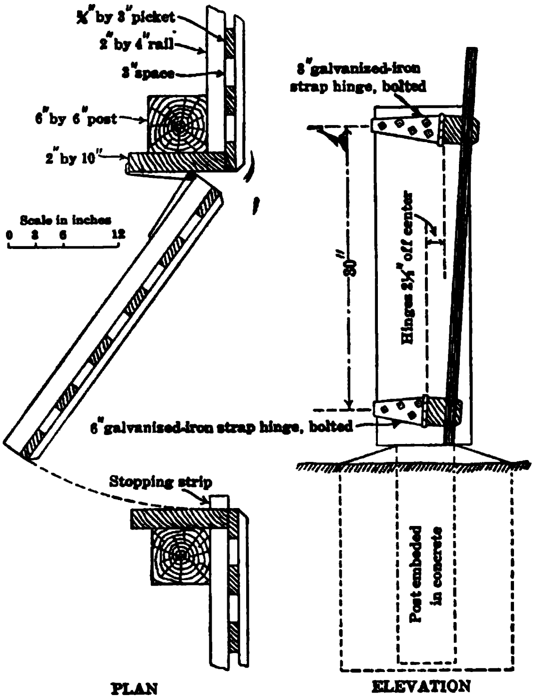


Figure 9.—Self-closing gate.

With the exception of air, water is perhaps the most important single element vitally affecting the health of every man, woman, and child in the community. Running water within the house should be regarded as a necessary article in a mining town, and not as a luxury. A spigot in the yard or in the street may have been sufficient for the "camp," but it is not in keeping with town life. The necessity of having good water should exert a powerful influence on the selection of the town site. The water system should have the approval of a competent sanitary engineer; his resourcefulness and wide experience with this phase of town building will be a guaranty against future regrets.

SOURCES OF WATER SUPPLY.

SHALLOW WELLS.

In many of the established mining towns the introduction of an expensive water system is impracticable, but reasonable measures should be taken to improve the unsatisfactory conditions that exist. Shallow dug wells with rope and bucket are in common use, and these are particularly susceptible to pollution when found in conjunction with other insanitary conditions. The most effective step toward improving the water supply from shallow wells is the abolishment of neighboring insanitary privies, stables, and pigsties.

DEEP-DRILLED WELLS.

It is easier to protect bored wells from pollution than dug wells, and if palatable water can be obtained at moderate depths wells should be bored throughout the village and equipped with easily operated hand pumps. If it is necessary to drill very deep for water, at least one such well should be drilled and equipped with a gasoline pump and the water distributed to taps situated at convenient places in the settlement.

SPRINGS.

If there is in the vicinity a spring that flows the year round and the water proves satisfactory upon analysis, it may be used for drinking and cooking; water from wells will do for washing and other household uses. The spring should be concreted to prevent local contamination, and the immediate surroundings and approaches to the spring should be improved and beautified. Periodical bacteriologic examination of the water should be made.

CISTERNS.

Unless no other source of supply is available at reasonable cost, drinking water should not be obtained from cisterns, although cisterns may be used to good advantage to supply water for general housework. In old mining towns unsightly conditions often develop in connection with the collection of rain water. Old tubs, kegs, and buckets of all shapes are kept around the kitchen door for the purpose of storing up the rain water. Mosquitoes breed in these vessels, with the result that skin inflammation, sleepless nights, and malaria follow. If it is necessary to collect rain water in the absence of cisterns, the company should furnish a neatly painted 50-gallon barrel, which should stand above the ground and be protected in such a way as to prevent mosquitoes from breeding in it.

MOSQUITO PREVENTION.[a]

The united and continued efforts of every one in the community are necessary if mosquito breeding is to be prevented. The company's efforts in draining swamps or filling in lowlands will be frustrated if careless tenants permit tin cans or broken crockery to lie around and collect stagnant water. All weeds in the yards, streets, and alleys should be cut, as they not only in themselves furnish sheltering places for mosquitoes but they conceal broken bottles and old shoes which will hold sufficient water for hundreds of "wigglers" to be hatched.

DISPOSAL OF WASTES FROM KITCHEN SINK.

CESSPOOLS.

When water is piped into the house some method of disposing of the waste from the kitchen sink must be provided. Individual leaching cesspools are unsatisfactory, chiefly because they do not remove the wastes from the zone of habitation. The soil surrounding the cesspool soon becomes saturated and choked with foulness, and rancid odors are given off which destroy the wholesomeness and healthfulness of the dwelling site. On warm sultry nights the odor is particularly obnoxious, but the evil is going on to just as great an extent at all times.

STREET GUTTERS.

In the absence of an underground sewer system, perhaps the best method is to build open concrete street gutters and utilize these for removing the kitchen wastes. The gutters are open to inspection at all times and can be flushed out regularly. In some cases it may be feasible to circulate mine water through the gutter system, which greatly improves conditions.

WASH AND CHANGE HOUSE.

It may not be practicable to install stationary bathtubs in all the individual houses. A cheaper and better arrangement, as far as the miners themselves are concerned, is the establishment of a wash and change house (Pl. V, *A*) at the mine mouth. These houses are being rapidly introduced at many mines throughout the United States, and their merits will be briefly discussed here. A paper on wash and change houses is being prepared and will be presented in a later publication of the bureau.

Mining necessarily is dirty work, but it does not follow that the miners should carry the evidence of their day's toil through the

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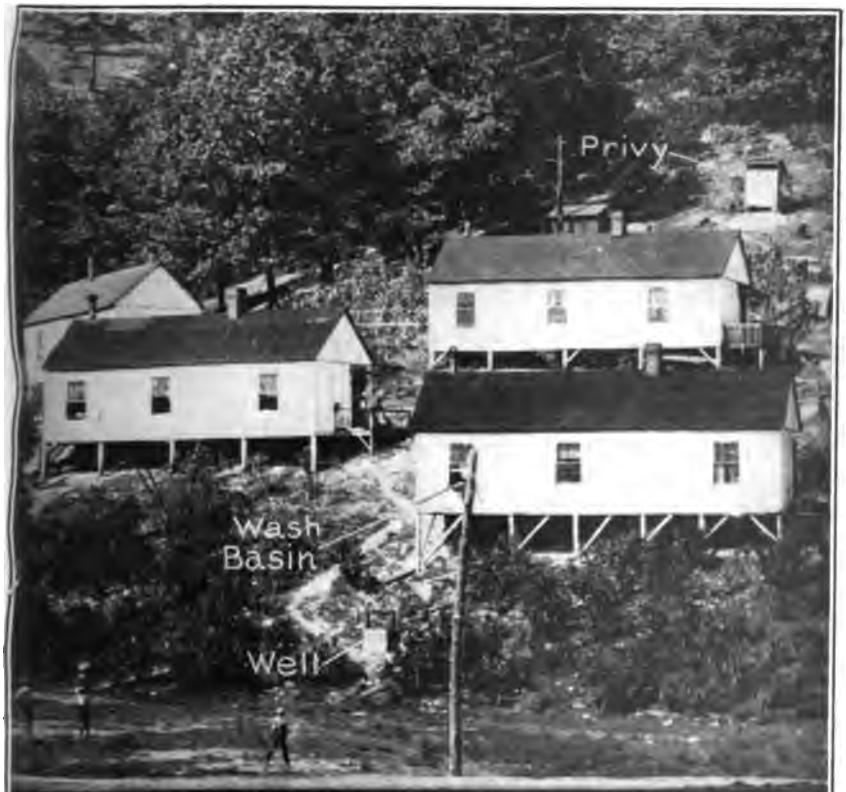
[a] For a fuller discussion of mosquito prevention see Howard, L. O., Remedies and preventives against mosquitoes: Farmer's Bulletin 444, U. S. Dept. of Agriculture, April, 1911.

A. CHANGE AND WASH HOUSE AT EDGEWATER, ALA.



B. INSANITARY ARRANGEMENT OF WELL, HOUSE, AND PRIVY.

streets and into their homes. Cleanliness in person and clothes stimulates self-respect, and, better still, indicates consideration for the people and property with whom one comes in contact on the streets, in the stores, or on the trolley cars. The wash and change house encourages these commendable traits. Its use also shows a consideration for the folks at home. It lightens the burden of keeping the house clean and does away with the necessity of lighting fires to heat water. Strict privacy in bathing in a miner's home is difficult because of lack of facilities, and the wash and change house relieves the many inconveniences necessitated where good standards of modesty are maintained.

The shower bath refreshes the workman so that he returns home in a more agreeable frame of mind. Fatigue is caused by the accumulation of the by-products of muscular activities, and experiments have shown that the shower causes the more rapid elimination of these toxins. The wash and change house helps to conserve health. Coming out of a warm mine, with damp clothes and feet wet because of inadequate drainage, the miner is susceptible to colds and pneumonia. The shower helps to restore his heated and perspiring body to normal temperature.

The wash and change house can be heated, lighted, and furnished with hot and cold water economically by utilizing the exhaust steam from the power plant. The plumbing fixtures and drainage system can be installed en masse at much less expense than at the individual houses and the maintenance and repair costs will be greatly reduced.

SEWER SYSTEMS.

As scientific investigations and practical observations have demonstrated that typhoid fever, hookworm, and many diarrheal troubles are disseminated by the careless disposition of fecal discharges, many of the loose practices formerly followed should no longer be tolerated. Reduced to the nauseating truth the question resolves itself into preventing the reentrance of bowel discharges into the system through such mediums as water, food, flies, dust, and common towels. How can this be best accomplished? In cities the method generally adopted is the immediate removal by means of water flushed through sewers to some distant point, where the sewage is emptied directly into some large body of moving water or treated in a disposal plant, the refinements of which depend upon circumstances. Two of the reasons why private communities often defer the building of a sewer system are: First, the convenience of a sewer system is never fully appreciated until it has once been enjoyed; and, second, a sewer is a buried investment and adds nothing to the appearance of the town, as surface improvements do. In the mining towns of the future the sewer system should be regarded preeminently as an agency of community health and should be installed if the cost is not prohibitive. As was true of the water supply, the possibility of an economical sewer system should be an important factor in determining the town site and town arrangement.

SUBSTITUTES FOR SEWERS.

In some new towns and in many old ones it may not, however, be feasible to install a sewer system, and a less expensive substitute must be selected. As the sewer system presupposes a public water supply, it is practically out of the question in many of the established mining towns. In selecting the substitute emphasis should be laid, first, on the feature that aims to get the body sloughings outside the zone of habitation as quickly as possible; second, on the prevention of nuisances between periods of removal.

SANITARY PRIVIES.

A sanitary privy is very practicable for mining towns, more so, indeed, than for isolated houses, because it can be taken care of much easier as a system than as a unit. A water-tight receptacle (preferably of metal) under the hole will prevent soil pollution and consequent contamination of wells. If lime or dirt from a convenient box is used to cover each stool, the odors and the danger of transmission by flies will be minimized. The receptacles should be emptied at least once a week during the cold months and twice a week during the hot summer season. An extra wagon load of buckets should be provided, so that it will be necessary only to exchange the empty bucket for the full one at the privy, deferring the emptying of the bucket until the wagon arrives at the disposal site. The material should be thoroughly limed and buried in a place where it is not possible to cause a nuisance or pollute a water supply. In some cases it may be advisable to burn the waste matter in an incinerator.

LEACHING VAULTS.

Leaching earth vaults are not satisfactory and have absolutely no justification in a mining town where community control reposes in a central authority. These vaults possess all the nuisances of the cesspool, with the very dangerous element of disease germs added. In wet seasons the ground is saturated, and instead of the liquid seeping out the ground water leaks into the vaults. When the water table lowers, the pollution from the walls will be carried great distances.

CONCRETE VAULTS.

The water-tight concrete vault is much better than the leaching type, but it is objectionable because the human wastes are stored continuously close to the human habitation. A second objection is the high cost and the difficulty of making the vault water-tight.

MAKE THE PRIVY SAFE.

In a number of old-type mining towns the privies are so built that the bowel discharges simply drop upon the surface of the ground, whence they are scattered about by animals, rain, wind, or flies. In conjunction with this crude arrangement are often found shallow wells which furnish drinking water for the people (see Pl. V, *B*). This deplorable and dangerous combination of conditions should be corrected at once. As a matter of relative importance, however badly the house of the miner may need repairs, the first and most important duty is to make the privy safe. The most illiterate man will discover a way of patching up his house to protect himself and his family from the cold, but he is not apt to guard against such insidious foes as typhoid-fever germs and hookworms.

CLEAN-UP DAY.

Many municipalities are adopting what is known as a clean-up day, which is a development of the spring and fall house-cleaning days.

This practice has been in vogue in some mining communities for many years. Some companies have recently made the clean-up day more ceremonious. The legend on a placard used by one company whereby better cooperation was obtained is given below. This placard also served a useful educational purpose.

CLEAN-UP DAY.

Saturday, April 5, has been set aside as "Clean-up Day" for all the camps of the * * * corporation, and it is hoped that every family will use some effort on that day to make our camps more healthful and sanitary than they have ever been.

Burn all trash, leaves, chips, bones, cast-off clothing, old shoes, etc.; in fact, everything that will burn that is of no value. Tin cans, old tin buckets, and things of that kind, should be heated until they melt or will not hold water. Stagnant water in such things is a breeding place for both malaria and typhoid fever.

Scald out the rain barrel and cover it with a coffee sack or cotton cloth. This will keep out the wiggletails. Every "wiggle" will be a "skeeter" bye and bye.

Cinders, old iron, crockery, and things that will not burn should be piled in some place convenient for a wagon. Arrangements have been made to have the company team haul this rubbish away.

Clean out well from under the floors and fix so that neither hogs, dogs, nor chickens can stay beneath them. Fleas and flies both spread disease. Sufficient lime to sprinkle under a house will be furnished by the company, free of charge, when properly applied for.

Flies are the cause of 75 per cent of the typhoid fever in this country. Wall up, or box up, around the privy vault, and throw on sufficient dirt to

make it fly tight. Scrub out the closets at least once a week with hot soap suds and pour a little lime and coal oil in the vaults occasionally. Screen your house early and well against the fly. Mosquito bar is cheap and answers well for one season. Mr. Fly takes his breakfast in the outhouse and his dinner with you, and is not at all particular to take off his hat or wipe his feet when he comes in.

We are anxious to make these camps the model sanitary camps for the State of Kentucky. We will do our part. Will you help?

(Signed by officers of corporation.)

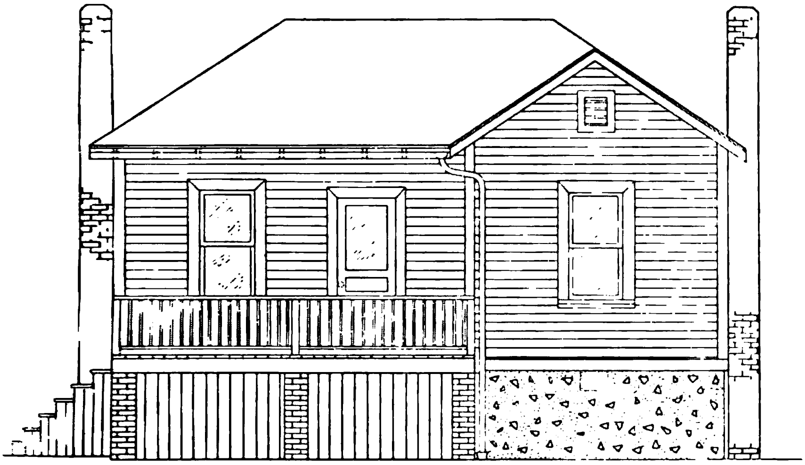
REGULAR SCAVENGER SERVICE.

Clean-up days serve a purpose, but they should not by any means be considered a substitute for regular scavenger service. A system based upon the frequent removal of garbage, rubbish, ashes, and other wastes, is by far the most sanitary. A water-tight receptacle. protected from flies and animals, and small enough to be handled by one man is recommended. If such receptacles are placed near the alley so that the scavenger can load them quickly it may be possible to visit each house every two or three days. This material should be burned or buried in such a manner so that no nuisances will arise.

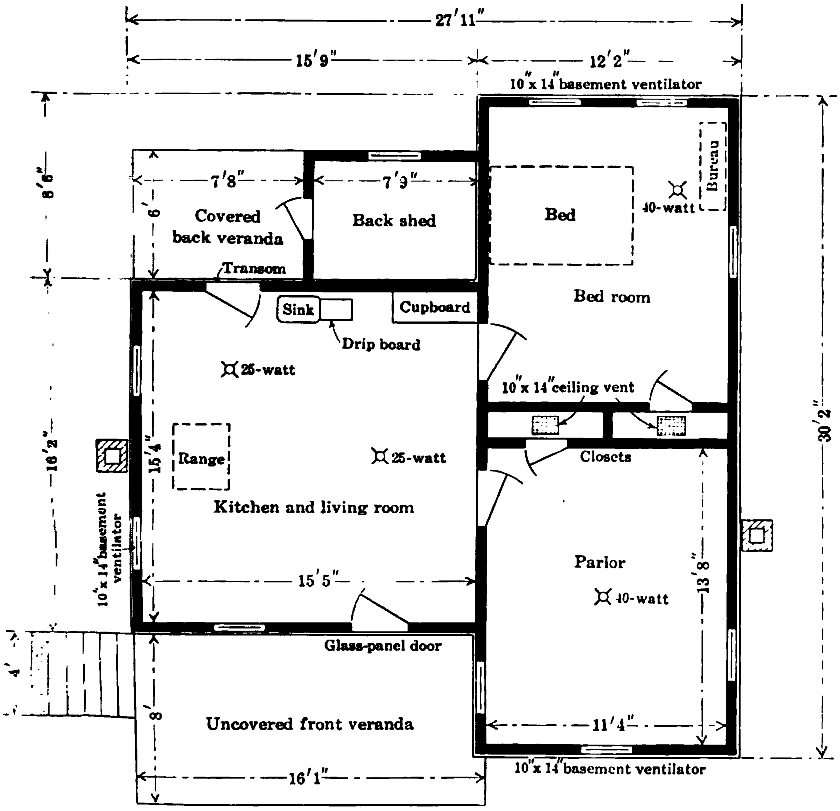
DETAILED PLANS.

Plates VI, VII, and VIII will aid the operator in drawing up plans and specifications for cottages to be built by contract. Many of the suggestions contained in the bulletin are incorporated into these drawings. The special features of the cottage are: Substantial, well-ventilated foundation wall; double flooring lined with paper; large window area with weighted sashes; glass-panel front door and transom over back door; ventilators in closets and louvers in gables; roomy kitchen facing both street and back yard; spacious front veranda facing northeast; usefully located electric lights.

Although these plans have been put to a practical test they should not be followed blindly, as local conditions might require numerous revisions to be made.



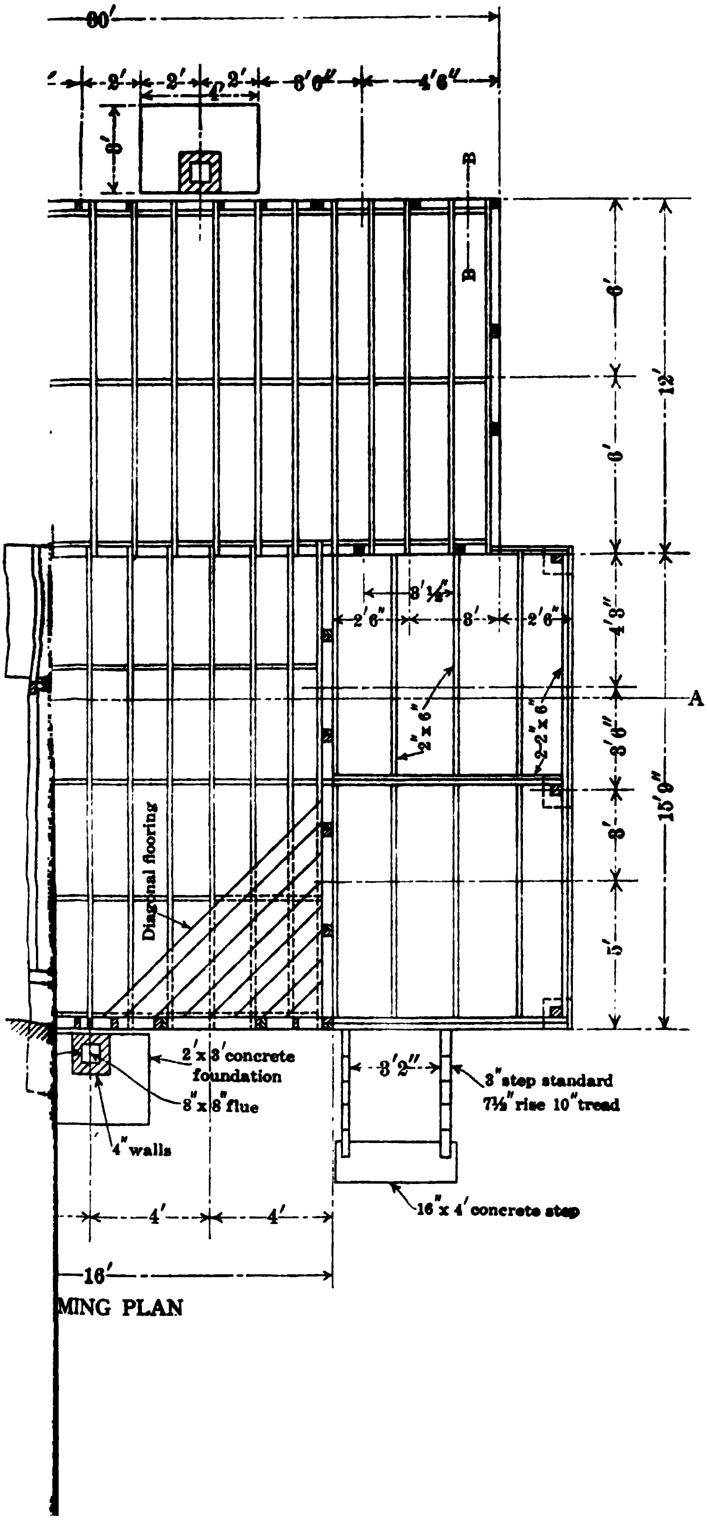
FRONT ELEVATION



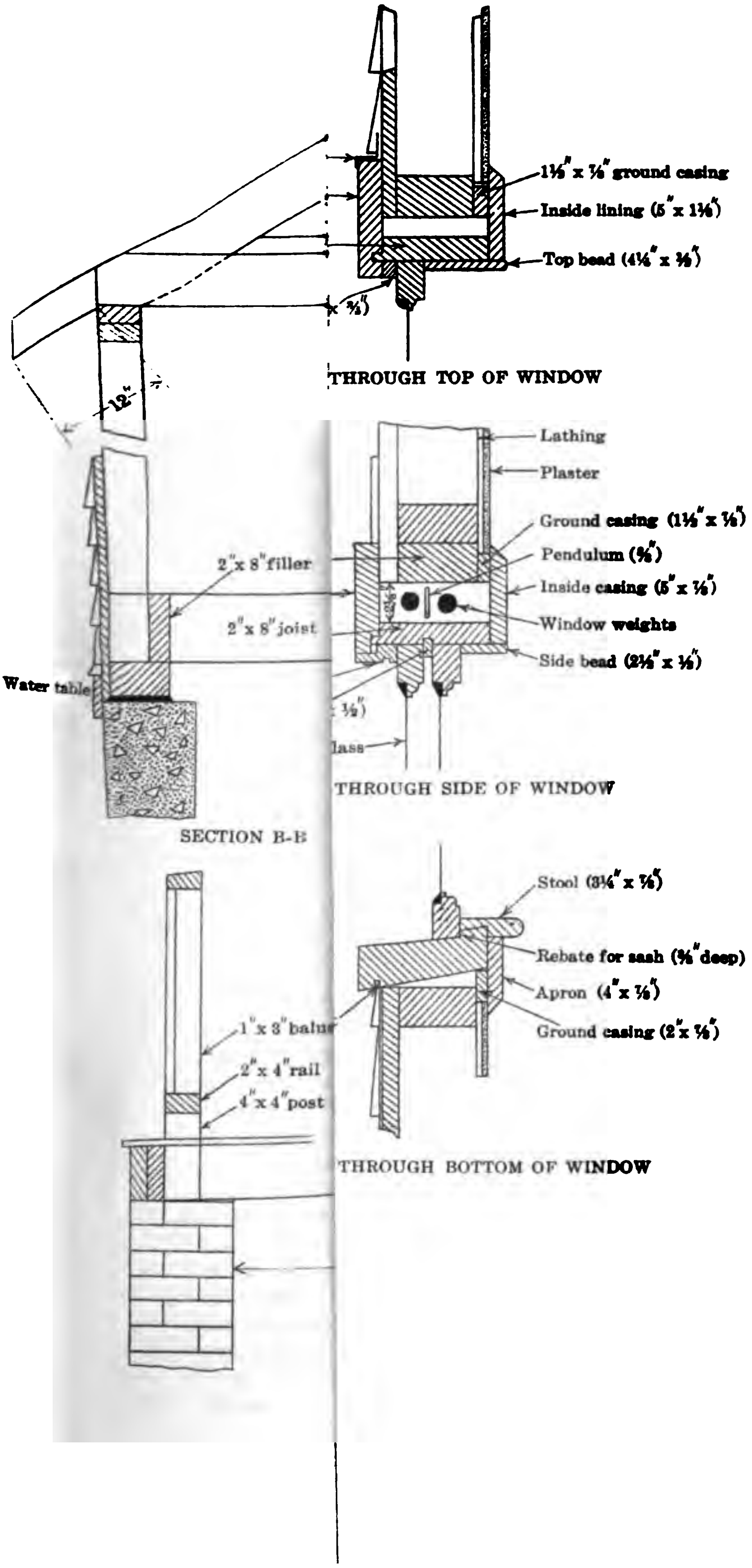
FLOOR PLAN

PLAN AND ELEVATION OF MINER'S FRAME COTTAGE.

80'
2'
8'


30′
2′
2′
2′
4′
3′6″
4′6″
8′
B
B
6′
6′
12′
3′ 1/2″
2′6″
3′
2′6″
4′3″
A
2″x 6″
2-2″x 6″
3′6″
15′9″
3′
5′
Diagonal flooring
2′x 3′concrete foundation
8″x 8″flue
4″walls
3′2″
3″step standard
7½″rise 10″tread
16″x 4′concrete step
4′
4′
16′

MING PLAN


1½" x ⅞" ground casing
Inside lining (5" x 1⅛")
Top bead (4¼" x ⅜")
x ⅜")
12"
THROUGH TOP OF WINDOW
Lathing
Plaster
Ground casing (1½" x ⅞")
Pendulum (⅜")
Inside casing (5" x ⅞")
Window weights
Side bead (2½" x ½")
2" x 8" filler
2" x 8" joist
Water table
½")
lass
THROUGH SIDE OF WINDOW
SECTION B-B
Stool (3¼" x ⅞")
Rebate for sash (⅜" deep)
Apron (4" x ⅞")
Ground casing (2" x ⅞")
1" x 3" balu
2" x 4" rail
4" x 4" post
THROUGH BOTTOM OF WINDOW

PUBLICATIONS OF MINE ACCIDENTS AND METHODS OF MINING.

A limited supply of the following publications of the Bureau of Mines is temporarily available for free distribution. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

BULLETIN 10. The use of permissible explosives, by J. J. Rutledge and Clarence Hall. 1912. 34 pp., 5 pls., 4 figs.

BULLETIN 15. Investigations of explosives used in coal mines, by Clarence Hall, W. O. Snelling, and S. P. Howell; with a chapter on the natural gas used at Pittsburgh, by G. A. Burrell, and an introduction by C. E. Munroe. 1911. 197 pp., 7 pls., 5 figs.

BULLETIN 17. A primer on explosives for coal miners, by C. E. Munroe and Clarence Hall. 61 pp., 10 pls., 12 figs. Reprint of United States Geological Survey Bulletin 423.

BULLETIN 20. The explosibility of coal dust, by G. S. Rice, with chapters by J. C. W. Frazer, Axel Larsen, Frank Haas, and Carl Scholz. 204 pp., 14 pls., 28 figs. Reprint of United States Geological Survey Bulletin 425.

BULLETIN 42. The sampling and examination of mine gases and natural gas, by G. A. Burrell and F. M. Seibert. 1913. 116 pp., 2 pls., 23 figs.

BULLETIN 45. Sand available for filling mine workings in the northern anthracite coal basin of Pennsylvania, by N. H. Darton. 1913. 33 pp., 8 pls., 5 figs.

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DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
JOSEPH A. HOLMES, DIRECTOR

THE CONDENSATION OF GASOLINE FROM NATURAL GAS

BY

GEORGE A. BURRELL, FRANK M. SEIBERT
AND
G. G. OBERFELL

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THE CONDENSATION OF GASOLINE FROM NATURAL GAS.

By GEORGE A. BURRELL, FRANK M. SEIBERT, and G. G. OBERFELL.

INTRODUCTION.

The Bureau of Mines is conducting a series of investigations with the common aim of minimizing the losses that occur in the mining and treatment of mineral substances. The results of the investigations are being published in reports of the bureau. This report treats of a method of preventing some of the waste of the natural gas incidental to oil mining. This method, the condensation of gasoline from natural gas, offers to the oil operator and others a profitable means of utilizing some of the oil-well gas now being wasted. The most desired constituent of crude oil is obtained, the production of oil is not hindered, and the gas, after the extraction of gasoline, can be returned to the leased area to drive pumps or into pipe lines for uses to which natural gas is ordinarily put, usually with its fuel value lessened only in slight degree.

Publications already issued [a] briefly discuss the subject. In this report the work is treated in greater detail, and the results of many additional tests are shown.

GENERAL STATEMENT REGARDING WASTES OF NATURAL GAS.

Arnold and Clapp [b] classify as follows the various ways in which natural gas is wasted:

- (*a*) In drilling and casing wells.
- (*b*) From high-pressure wells.
- (*c*) In oil production.
- (*d*) Through lack of proper care of wells.
- (*e*) In transportation.
- (*f*) In utilization.
- (*g*) Through improper plugging of wells.

This report concerns itself with method *c*, the waste incident to oil production.

A. B. Macbeth, chairman of a committee on conservation appointed by the Natural-Gas Association of America, presented at the annual meeting of the association in Cleveland, Ohio, in May, 1913, a report[a] covering in brief different phases of the subject of the waste of natural gas. Following is an extract from that report, which defines the position of oil operators as regards waste in a new field:

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[a] Allen, I. C., and Burrell, G. A., Liquefied products from natural gas; their properties and uses: Technical Paper 10, Bureau of Mines, 1912, 23 pp.; Burrell, G. A., and Seibert, F. M., The sampling and examination of mine gases and natural gas: Bull. 42, Bureau of Mines, 1913, 116 pp.

[b] Arnold, Ralph, and Clapp, F. G., Wastes in the production and utilization of natural gas and means for their prevention: Technical Paper 38, Bureau of Mines, 1913, 29 pp.

> Where oil and gas are found in the same field, it is the general practice to blow off the gas. In some fields where the rock pressure is low and the production of both oil and gas is small, some operators are able to produce and market both oil and gas from the same sand. In large operations no practicable way is found of obtaining the oil without wasting the gas, and this is the principal cause of the depletion of many gas fields, and is responsible for a greater waste of gas than all other causes put together. It is natural for the owners of a well to want to produce and sell the well's full production, whether oil or gas, in the shortest possible time, but it is impossible to market gas in the way oil is marketed, for gas can not be stored like oil. The committee saw no way of saving the gas from these wells without seriously affecting the oil production.

Arnold and Clapp,[b] Arnold and Garfias,[c] and Blatchley[d] also discuss various means of preventing the waste of natural gas. They briefly mention the production of gasoline from gas. Arnold and Clapp[e] state that at some wells the value of the recoverable gasoline in the gas is worth as much as 20 per cent of the oil produced,and that it is not extravagant to estimate the loss in gasoline, at 10 per cent of the oil produced, or, up to 1912, a clear loss of $4,000,000.

OCCURRENCE OF GAS AND OIL.

Gas may be found in a sand and separate from oil. It may be found in more than one sand separate from the oil, or the gas sand may be just above and in contact with the oil sand. A given sand may produce oil and gas in one place and in another part of a territory gas only.

Gas may come from the same sand as the oil itself. It is this manner of occurrence of gas and oil that the authors desire to emphasize, for under these conditions the gas is frequently mixed with enough of the gasoline constitutents of the oil to warrant the erection of a plant for the purpose of condensing the gasoline.

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[a] Report of committee on the conservation of natural gas: Proc. eighth ann. meet. Natural-Gas Assn. Am., vol. 6, 1913, p. 240.

[b] Arnold, Ralph, and Clapp, F. G., Wastes in the production and utilization of natural gas, and means for their prevention: Technical Paper 38, Bureau of Mines, 1913, 29 pp.

[c] Arnold, Ralph, and Garfias, V. R., The prevention of waste of oil and gas from flowing wells in California, with a discussion of special methods used by J. A. Pollard: Technical Paper 42, Bureau of Mines, 1913, 15 pp., 2 pls., 4 figs.

[d] Blatchley, R. S., Waste of oil and gas in the Mid-Continent fields: Technical Paper 45, Bureau of Mines, 1914, 57 pp.

[e] Arnold, Ralph, and Clapp, F. G., op. cit., p. 11.

The gas usually finds its way to the atmosphere through the space between the casing of the well and the tubing inserted for the removal of the oil. This gas is the so-called "casing-head gas." At the beginning of an oil flow when the flow is natural, a large quantity of gas escapes to the air through the same tubing as the oil. Where the gas finds its exit to the atmosphere apart from the oil at the casing head it is a simple matter to make pipe connections between the casing head and any desired point where the gas is to be utilized. This is frequently done when the supply of casing-head gas is sufficient to warrant its utilization, but frequently, when the supply exceeds the small demands of the lease, the excess is wasted.

When a well is first drilled, the quantity of gas escaping with the oil from the tubing is frequently enormous, being 10,000,000 to 15,000,000 feet or more at times. This gas is wasted. The flow in time diminishes.

When gas comes with the oil in the flow pipe, the two are often separated by means of a gas trap. The oil, entering the top of a drum, settles to the bottom and is withdrawn, and the gas flows off at the top. Many of the plants in California utilize gas that flows with the oil for condensing gasoline. One gasoline plant in the Cushing field, Okla., also uses trap gas. A new type of trap for saving gas from gushers and separating the gasoline is described at the end of this report (p. 99).

Oil wells that have passed the flowing stage and are being pumped may still continue to give off much gas at the casing head. The quantity may vary from little or nothing at some wells to 500,000 cubic feet or more at others. When enough of the gas is available, it is used for pumping on the lease, the excess being wasted. A steam pumping engine of 50 horsepower requires about 25,000 cubic feet of gas for 10 hours' operation. From 12 to 15 cubic feet of natural gas is needed per horsepower-hour for gas engines that are used on leases for pumping oil wells. If there is not enough of the gas available for working pumps, it is all allowed to go to waste, or perhaps some is used for heating and lighting a few scattered houses on the lease.

The efficient utilization of the wasting casing-head gas ordinarily is a difficult problem. The many miles of pipe that would have to be laid to transport it from a field would usually be an unwarranted expense. However, some towns, among which may be mentioned Warren, Pa., and Sisterville, W. Va., are lighted and heated largely with casing-head gas.

In general, however, the oil man considers casing-head gas as waste gas and its escape necessary in oil-well operations, to permit the maximum flow of oil into the well from the surrounding strata.

Huntley[a] discusses the free escape of gas as one of the causes of the decline of oil fields, the action being somewhat as follows:

(1) Excessive refrigeration due to the free expansion of large quantities of gas forms waxy sediments in the productive stratum and in the tubing of the well. This sediment obstructs the passage of the oil from the sand.

(2) The gas in the immediate vicinity of the well dissipates itself in the initial flow, and the oil production therefore falls off, owing to a lessening of the expulsive force.

The rapid exhaustion of the gas in a certain part of the field may remove the only influence retarding the encroachment of water, which may, by a flanking movement, cut off a large section of the producing area; or water may exist in the lower part of the oil sand, being held in check only by the rock pressure of the gas. If each cubic foot of gas were retained to perform its work of expelling petroleum the pressure would help to retard the water for a considerable period, or until the maximum amount of oil could be recovered. Huntley[b] cites the Hogshooter pool in Oklahoma as an example of a producing gas district that was ruined by having its gas drained too rapidly. Wells were constantly drawn upon to their utmost capacity; hence as no pressure restrained the water under high pressure in the lower part of the productive formation the water flooded one well after another.

FACTORS AFFECTING FLOW OF GAS AND OIL IN DIFFERENT SECTIONS OF THE SAME FIELD OR IN NEIGHBORING WELLS.

The concern of the operator of a plant for making gasoline of natural gas covers all phases of the industry from the occurrence of gas and oil in the well to the final disposal of the gasoline. Hence, in the following pages, is given a brief summary of some of the views that are held regarding the factors that affect the occurrence of gas and oil underground. These views are fully discussed in reports of the United States Geological Survey.

The operator is frequently puzzled to know why wells in one part of a field are more productive than are others in the same field, or why adjoining wells or wells on the same lease, are so erratic as regards output. Another question that may occur to him is why a particular field is productive and an adjoining territory nonproductive. Many observations have shown that the strata yielding oil and gas are practically identical, the gas usually accumulating in the domes of the arches in the strata or in other elevated parts of the deposits. Gas almost invariably accompanies oil where conditions favor its accumulation, but oil is frequently found almost unaccompanied by gas on account of the collection of the gas in the highest portions of the strata or because of its escape through imperfections of the covering layers. Brine almost universally accompanies the oil and gas.

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[a] Huntley, L. G., Possible causes of the decline of oil wells and suggested methods of prolonging yield: Technical Paper 51, Bureau of Mines, 1913, pp. 6-7.

[b] Huntley, L. G., op. cit., p. 7.

In addition to possessing a porous structure for holding the oil or gaseous contents, the reservoir rock must be entirely covered with an impervious layer, the commonest and most perfect cover being a fine-grained shale, whose imperviousness and freedom from fracture enables the "sand" to retain the gas or oil. Gas, oil, and water are frequently found distributed according to their specific gravities, gas disengaging itself from the fluid and rising to the highest point in the beds, and water displacing the oil and finding a resting place as low down as possible. When oil and gas strata are comparatively little undisturbed, each well usually draws its supplies from a considerable area; indeed, the owners of wells in the United States are usually compelled to continue to raise oil, without regard to the conditions of market, to prevent its being obtained by neighboring leaseholders. On the other hand, faults and dislocations of strata may limit the area over which a single well draws its supplies, and so impede the free passage of the fluid that the pressure is small. It is now generally admitted that the pressures in wells are entirely due to accumulations of gaseous hydrocarbons, chiefly methane, which were formed with the liquid hydrocarbons and exist in a highly compressed condition and dissolved in the petroleum or accumulated in the beds immediately overlying the oil stratum. Where the gas has been allowed to escape freely, petroleum rarely flows from a well, and never, perhaps, unless left for a long time, rises to the surface unaided.

Discrepancy in production may in some cases be attributed to local variations of the reservoir rock, but Arnold and Garfias [a] state that an abnormally low production of oil can be traced to one or more of the following causes: Inefficient management; improperly finished well; poor condition of casing; failure to perforate casing, or inadequate size and number of perforations; obstruction of the bore-hole by tools or fragments of débris; failure to exclude water, which sometimes results in the inrush of sand; effect of neighboring wells; and drawing on a secondary sand only. Some of these causes affect the yield of gas also. Arnold and Garfias [b] add that although at some wells conditions can not be remedied, and at others the expense incurred would not be compensated by the added production, nevertheless, in most instances, an intelligent study of the trouble and its sources will disclose some comparatively simple means of improving conditions so as to increase the total yield.

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[a] Arnold, Ralph, and Garfias, V. R., Methods of oil recovery in California: Technical Paper 70, Bureau of Mines, 1914, p. 9.

[b] Arnold, Ralph, and Garfias, V. R., idem.

EFFECT OF DRILLING NEIGHBORING WELLS.

Regarding underground connection between neighboring wells Huntley [a] has the following to say:

> The first well drilled in a group will tend to set up drainage channels and divert large quantities of oil from a considerable area. Subsequent wells come in as much smaller producers than the original well. Again, in loose unconsolidated sands, such as are found in the Caddo field in Louisiana, and in the famous Glenn pool, in Oklahoma, if a well stops pumping for a day, the surrounding wells extend their own channels, breaking down the drainage systems of the first well, to the extent that it is often difficult to again recover oil from the well that has stopped pumping. As a result the wells in the Glenn pool are pumped 24 hours a day, 365 days in a year. The condition of the sand in the Glenn pool was brought about somewhat artificially by the use of enormous quantities of nitroglycerin in shooting. The sand, originally coarse and porous, has probably been shattered throughout the entire producing area.
>
> In certain lenticular formations, described by the oil man as "spotty," of two wells drilled only 150 feet apart, one has been a large producer and the other a dry hole. This discrepancy may be due to drainage conditions or may be caused by an intervening hard spot in the oil sand. If it is caused by drainage conditions, the stopping of the producing well would probably cause the other to produce. Again, wells 1,000 to 2,000 feet apart are in places so closely connected underground that the muddy water used in drilling one well has been pumped out by another well a considerable distance away, not necessarily the well nearest to the one being drilled.

Huntley [b] further states that in a tight sand neighboring wells do not affect each other to the same degree as in a very porous stratum; that is, such pronounced drainage channels toward the wells first drilled are not formed.

EFFECT OF FORMATION OF WAXY SEDIMENT.

Most of the plants for making gasoline from natural gas draw the gas from old wells, many of which are very small producers of oil. Hence many of them have not received much attention as regards upkeep. One result of this inattention is the formation of waxy sediment or paraffin. Regarding the formation of this waxy sediment Huntley [c] comments as follows:

> Petroleum in the so-called paraffin-oil fuels consists of hydrocarbons of the paraffin series, which range from the heaviest oil to the lightest gas. The gaseous constituents of petroleum exist in what may be likened to solution, much like the gas of soda water, and as such expand and escape when the pressure is relieved by a well. The sudden expansion and volatilization of such light hydrocarbons has a refrigerating effect, like the expansion of ammonia gas in an ice machine, chilling the remainder of the liquid petroleum and causing the separation of the heaviest paraffin as a waxy sediment. * * * This, * * * along with water and fine rock sediments, clogs the pores of the sand and obstructs the passage of the oil into the well.

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[a] Huntley, L. G., Possible causes of the decline of oil wells and suggested methods of prolonging yield Technical Paper 51, Bureau of Mines, 1913, pp. 23-24.

[b] Huntley, L. G., op. cit., p. 22.

[c] Huntley, L. G., op. cit., p. 6.

HISTORY OF THE MAKING OF GASOLINE FROM NATURAL GAS.

That gasoline can be extracted from natural gas has long been known, ever since oil and gas have been noticed in some gas pipe lines, but the production of gasoline from natural gas has only within the past few years become of commercial consequence, owing principally to the ever-increasing demand for gasoline.

TWO SUCCESSFUL PLANTS IN 1904.

A. Fasenmeyer made gasoline from the gas of oil wells near Titusville, Pa., in the fall of 1904. His plant is almost within sight of the old Drake well. His first equipment was crude. The gas from the wells after passing through the gas pumps was cooled by means of a coil of pipe placed in a tank of water. The condensate produced was allowed to drip into a wooden barrel. The losses resulting from evaporation were large. The product when first collected had a gravity of 80° to 90° on the Baumé scale. His production the first year was approximately 4,000 gallons, for which he received 10 cents per gallon. Tompsett Bros., of Tidioute, Pa., claim to have preceded Fasenmeyer in the making of a commercial venture out of the process. They are operating successfully at the present time.

As these ventures proved a commercial success attention was turned to the designing of better plant equipment. Gas and oil operators in other oil fields in the United States proceeded to install gasoline plants.

EARLY METHODS.

At first common gas pumps, with pressures not exceeding 50 pounds per square inch, were used. Condensation was effected by running a pipe through the earth to the gasoline receivers. Mr. William Richards, of Warren, Pa., claims to have been the first to install high-pressure compressors. His first experiments, made in 1905, were with pressures of 400 pounds per square inch. Later he came to the conclusion that a pressure of 250 pounds per square inch was sufficient to make gasoline that was about right for shipping. Mr. Richards's plant was located at Mayburg, Pa.

In the first plants for making gasoline from natural gas the cooling system consisted in general of a series of pipes. In some plants the pipes were cooled by the air, but in most plants were immersed in tanks containing water or else the water was allowed to drip over the pipes. At most plants the collecting tanks were open to the atmosphere. The residual or waste gases were allowed to escape. After the condensate had "weathered"—that is, when the lighter fractions had been allowed to volatilize and escape into the atmosphere—the product was marketed.

LATER IMPROVEMENTS.

The next step in the industry was to pass the gases from collecting tanks from the single-stage compressor through a higher-stage compressor. The gases were again cooled. In this manner a second and more volatile product was obtained, which was mixed with the product from the first-stage compressor. This mixture was again "weathered" and then marketed. F. P. Peterson, while connected with a gas-engine company in Grove City, Pa., claims to be the first to use the two-stage compressor method. As producers realized the great waste involved in this process, another improvement was introduced, as follows:

The condensate produced from both stages of compression and cooling, which had a gravity of 80° to 100° B., was mixed with refinery napthas until the specific gravity had been lowered to 60° to 76° B. By this means there was obtained a product that evaporated more slowly than did the condensate. The process of blending is more fully discussed elsewhere in this report.

The waste gases, after the gasoline had been extracted, were in part used for plant operation, and, in some plants, the remainder was returned to gas mains which supplied towns with gas for lighting and manufacturing purposes. In most plants the waste gases were allowed to escape into the atmosphere. At present much information is at hand as the result of the experimental work done, so that plants are now installed to meet particular requirements. The advisability of employing single or double stage compressors, the pressures to be used, the method of handling and disposing of the condensate, and the disposition of the waste gases are all considered.

PATENTS ISSUED.

Chute [a] gives the various patents that have been taken out covering the condensation of the hydrocarbons in natural gas, as follows:

In 1866 Johnson received patent No. 54910 which clearly discloses the art of rendering liquid the vapors that rise with or are forced up with petroleum.

In the Heinzerling patent of 1897, No. 575714, which expired January 28, 1914, there is shown an air-compressor or gas-compressor cylinder and a gas-expansion cylinder, both coupled to a flywheel, with a series of condensers and heat exchangers between. The specification clearly explains that the gas is to be compressed in the first cylinder and cooled in two condensers in series, with condensation of the condensible liquids, which are removed by appropriate valved containers depending from and connected with the condensers. Thence the water-cooled gas passes to other condensers cooled by the residual gas, which is in the meantime expanded in the second cylinder, thus aiding the compression. The expansion produces cold gas which afterwards, circulating through the last condensers, cools the compressed gas to a point stated to be between -25° and -40° C. (-13° to -40° F.). The first water cooling is stated to refrigerate the gas to 10° C. (50° F.).

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[a] Chute, H. O., The patent processes for making casing-head gasoline: Jour. Met. and Chem. Eng., vol. 12, No. 3, March, 1914, pp. 147 and 148.

Among the earlier unexpired patents is No. 668197 of 1901, issued to Seceur, which claims a process of liquefying methane from natural gas.

In 1907 patent No. 867505 was granted to Dennis Hastings and W. Brink. It discloses that natural gas, after having been artificially compressed, is brought into contact with water which serves to cool the gas; later water or oil is atomized to intermingle with the gas to cool it. The claims are for an arrangement of apparatus.

In 1909, John L. Gray obtained patent No. 993976, for certain apparatus for obtaining gasoline from the casing-head gas. The claims are for an organization of apparatus for separating, first, any engine or cylinder oil from the gas by means of the ordinary steam trap or oil trap used on steam lines, a condenser with another oil trap beyond, and a relief valve which is an ordinary steam safety valve. There is also a pot steam trap to separate the condensed gasoline from the gas, and a receiving tank.

Chute[a] states that in the processes now in successful use the essential steps have been covered by expired patents.

Patents covering the separation of the light paraffin hydrocarbons in natural gas are described in the appendix at the end of this report.

PRODUCTION OF GASOLINE FROM NATURAL GAS IN THE EASTERN PART OF THE UNITED STATES.

In the Appalachian oil fields the utilization of casing-head gas for making gasoline is more extensive than in the Mid-Continent or California fields. The industry had its commercial inception in Pennsylvania and West Virginia. East of the Mississippi River the approximate number of plants in commercial operation was about 253 in July, 1913. The plants were distributed among the various States about as follows: New York, 1; Pennsylvania, 100; West Virginia, 100; Ohio, 47; Illinois, 5. The industry in these States is firmly established, and new plants are being built even in places where many thought that installations would not be placed.

THE GASOLINE INDUSTRY IN WEST VIRGINIA.

The industry of making gasoline from natural gas has made fairly rapid progress in West Virginia in the past few years. In that State gasoline was first made from natural gas in 1905. There were in July, 1913, about 100 plants in the State. The production from 10 plants exceeded 500 gallons per day and from 5 exceeded 1,000 gallons per day. The production of the remaining plants ranged from a few gallons up to 500 gallons per day. The number of wells connected to each plant varies from 1 or 2 up to 100, with an average of about 15 to 20. Of the total number of oil wells in the State, about 1,500 are utilized for gasoline production. The production is confined almost exclusively to 12 counties—Brooke, Calhoun, Hancock, Harrison, Marion, Marshall, Pleasant, Richie, Tyler, Wetzel, Wirt, and Wood. The total production for 1913 was 7,662,493 gallons.[a] Hill[b] states that in 1912 there was produced 5,318,136 gallons.

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[a] Chute, H. O., op. cit., p. 148.

Tyler and Pleasant Counties produce about 75 per cent of the total quantity of gasoline produced in the State. In Tyler County are five productive oil sands. The gas utilized for gasoline production accompanies the oil in the Big Injun sand. In Pleasant County the gas utilized is chiefly from oil wells tapping sands in the Berea grit. This sand lies below the Big Injun. The wells from which the natural gas is derived in these fields are from a few years to 20 years old, some of the first wells drilled still producing vapors of the heavy hydrocarbons. The highest pressures utilized for making gasoline in West Virginia are about 150 pounds per square inch, none being over 250 pounds. Two plants at Follansbee, W. Va., use the pressure last mentioned.

Of about 14,000 producing oil wells in the State approximately 1,500 are utilized for gasoline production. Day[c] gives 13,014 as the number of producing oil wells in the State at the end of the year 1911. This was an increase of 279 wells over the year 1910. At the present time the authors estimate that there are 14,000 wells in the State. This estimate is based only on what seems to be a reasonable increase in two years' time over the production for 1911 as given by the Geological Survey. The rate of increase in production for the two years 1912 and 1913 is greater than during the preceding two years largely because the price of petroleum increased decidedly for a time.

THE INDUSTRY IN PENNSYLVANIA.

The industry in Pennsylvania during 1912 and 1913 has made rapid progress. At the close of 1913 there were nearly 100 plants in successful operation. The industry is confined almost entirely to the counties of Butler, Forest, McKean, and Warren.

Most of the plants are rather small, few producing 500 gallons per day. The average plant produces only about 200 gallons per day. The number of wells used for making gasoline is 1,100 or 1,200.

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[a] Hill, B., Natural gas: Mineral Resources U. S. for 1913, U. S. Geol. Survey, 1914, p. 1481.

[b] Hill, B., Natural gas: Mineral Resources U. S. for 1911, U. S. Geol. Survey, 1912, p. 348.

[c] Day, D. T., Petroleum: Mineral Resources U. S. for 1911, U. S. Geol. Survey, 1912, p. 351.

There were in 1913 about 56,000 producing oil wells in the State. Day[a] gives 52,545 as the total number of producing wells in the State for 1911. The increase for the year 1912 was 1,645 wells and for 1913 was 2,065 wells.

The output of gasoline for the year 1913 was 3,680,096 gallons.[b] The production for 1912 was 2,041,109 gallons.[c] The drawback to development in the northern counties lies in the lack of satisfactory transportation facilities. Most of the gasoline is hauled in tank wagons to the refineries where it is blended with naphtha. Some producers are forced to haul their product as far as 15 miles in tanks. When better facilities shall have been provided for transportation, thereby cutting down considerably the cost of production, there will be a wider expansion in these oil fields. Less than 2 per cent of the producing oil wells are utilized for the production of gasoline, as against 10 per cent in West Virginia.

The gases available in the Bradford County and the Warren County fields are from the third oil sand. The gases from most of the wells issue under a few pounds pressure. A small area around Tidioute, Pa., produces a gas consisting almost entirely of the vapors of the liquid hydrocarbons. These vapors are drawn out under a reduced pressure of 20 inches (12 pounds) of mercury. In no other field, to the authors' knowledge, are such "wet" gases encountered. The vapors after passing the vacuum pumps are simply cooled by means of running water. They are not compressed.

THE INDUSTRY IN CALIFORNIA.

PRODUCTION IN 1913.

Hill[d] states that the gasoline produced in California in 1913 was 3,460,747 gallons, valued at $405,186.

Gilmore[e] specifies the following production for California:

Company and field.	Gallons per day.
Puente Oil Co., Puente field	450
Pacific Gasoline Co., Brea Canyon, two plants	4,000
Union Oil Co., Santa Maria field	1,000
Standard Oil Co., Newhall field	450
American Gasoline Co., Santa Maria field	1,400
Purity Gasoline Co., Santa Maria field, two plants	1,700
Pinel Dome, Santa Maria field, two plants	3,500
Frank Hall, Santa Maria field	500
Olinda Gasoline Co., Olinda field	1,000
Hurley-Smith-Collins Co., Oleo field	2,500
A. F. Gilmore, Salt Lake field	450
Total	16,950

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[a] Day, D. T., Petroleum: Mineral Resources U. S. for 1911, U. S. Geol. Survey, 1912, p. 351.

[b] Hill B., Natural gas: Mineral Resources U. S. for 1913, U. S. Geol. Survey, 1914, p. 1480.

[c] Hill, B., loc cit.

[d] Hill, B., loc. cit.

[e] Gilmore Frank, Gasoline in California: Oil and Gas Jour., vol. 12, Oct. 9, 1913, p. 30.

NOTEWORTHY INTEREST IN THE INDUSTRY.

Gilmore[a] says further, regarding the gasoline industry in California:

> In the manufacture of this much-needed commodity [gasoline] more interest has been shown during the past year than in oil. Many experiments have been made and every theory brought forth and worked upon to bring out the greatest percentage possible in extracting the motor fuel from crude oil and gas. Refrigerating and freezing processes have worked overtime and enthusiastic estimates of the possibilities likely to be attained have been published, leading to the belief that the very air around an oil well would be converted into liquid, but from general observations made in the field most of these experiments are still in their incipiency. It has been demonstrated that low-gravity oil and its gas do not contain proportions of gasoline equal to those of the higher grade, and every effort to bring out and increase the percentage has been a failure. It is contended that the gas found in the Olinda field and worked out through the refrigerating process contains a larger percentage than could be given by the compressor method. This is a matter of theory alone. The "plant" so far has not proved its efficiency over the latter method and has fallen far short of expectations. They are making about 1,000 gallons per day. The same results and possibly better would have been obtained with the compressor system. They claim, however, that if the results are no larger the running expenses are considerably less.
>
> In the Santa Maria field, where the gravity of the oil runs above 30° B., gasoline of the best gravity is manufactured from casing-head gas. The field is noted for its large amount of escaping gas, and during the past two years a number of plants have been installed. Each of these up to the present time has shown an increase rather than a decrease in output, and what is more the operation of these "plants" has shown a tendency to increase the amount of production in the wells from which the gas is taken, the result of the vacuum caused in draining out the gas.
>
> ## MARKETING THE PRODUCT.
>
> Nearly all of the production of casing-head gasoline is marketed in southern California. The coast towns, such as Santa Barbara, Santa Maria, and Ventura, get a liberal supply from the Santa Maria field. The Pinel-Dome people ship their product here and market from tank wagons; the Purity gasoline is shipped to a distributing station here and is marketed in the city and through adjoining towns and cities. The Union Oil Co. markets the product of the Pacific Co. and its own.
>
> Investigations made prove that where the gravity is not lowered below 62° or 64° B. there is no perceptible difference between this article and that manufactured from crude oil. Wherever an inferior grade is placed on the market it is in every instance the result of reducing below the commercial grade by the application of too large a percentage of distillate, and this may happen to all grades. This is frequently the result of low prices being advertised, and until methods are adopted that will call for an inspector and impose a penalty for selling anything below a given specific gravity these dishonest methods will probably continue. These adulterations are brought about by the retailers, and not by the manufacturers, it is claimed.

Regarding immediate future developments Mr. Gilmore, in a letter to the authors, states that "the Union Oil Co. expected to extract with a new installation about 8,000 gallons per day from 8,000,000 cubic feet of gas, and a new plant owned by A. F. Gilmore is expected to add another 1,000 gallons per day, making a total of 25,450 gallons per day."

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[a] Gilmore, Frank, Gasoline in California: Oil and Gas Jour., vol. 12, Oct. 9, 1913, p. 30.

DISTRIBUTION OF PLANTS.

Laney [a] writes as follows regarding the production of gasoline in California.

> The coast-range mountains divide the State into two great groups known as the coast fields and the interior or valley fields. In the former group are the Santa Maria Ventura, Newhall, Salt Lake, and Fullerton-Whittier, while the Coalinga, Lost Hills, McKittrick, Kern River, Sunset, and Midway fields comprise the latter group. The valley fields have but one gasoline plant and that inoperative, while every field in the former group has one or more plants either in the course of construction or having been in actual operation for a year or more. And this in spite of the fact that production of both gas and oil in the valley fields is many times greater than that from the fields to the west of the mountains. That not all the gas is suitable for gasoline production is true, but it will undoubtedly be found when a thorough examination is made of these gases that the volume carrying considerable gasoline costituents is as great if not greater than in all the rest of the State taken together. The total number of gasoline plants in these fields is, at the present writing, 16, having a capacity in excess of 24,000,000 cubic feet of gas and producing upwards of 25,000 gallons of this valuable commodity daily.

METHODS EMPLOYED.

> In general the methods employed in recovering the condensible fraction from the gases in these fields are similar to those used elsewhere in the country, the variations being due to differences in local conditions. A great deal of the gas worked is obtained from flowing wells in combination with the oil and is separated in gas traps, being lead-line rather than casing-head gas. Naturally this gas is often far from clean, and in some cases leaves the trap at high temperatures (100° to 120° F.—38° to 49° C.), and it has been found necessary to use some form of precooling to lower the temperature before leading the gas to the machine, and in many cases scrubbers have been employed in order to remove the heavier distillates and any foreign matter that might work harm to the compressor cylinders and valves.
>
> The pressures used run generally from 210 to 250 pounds per square inch, with the exception of one plant using an ammonia refrigerating system where the product is obtained at 40 pounds pressure. There is one plant using three-stage compression; the majority use two-stage, but since their final pressures are 250 pounds the only apparent advantage of this variation is that they get one more cut in their product, and this advantage disappears when, as is done in most cases, the different cuts are all run into one stock tank and allowed to blend.
>
> The problem of final cooling of the compressed gas has been approached in a variety of ways, chief among which are, first, by allowing the compressed gas to expand through a controlling valve or an orifice around the pipe containing the incoming compressed gas; second, by means of an ammonia refrigerating plant, auxiliary to the main plant; and third, by expanding the compressed gas through a power cylinder and using the power thus made available for any one of a variety of purposes around the plant, such as redistributing the residue gas over the lease, assisting in the operation of the main compressor or operating another low-pressure compressor cylinder in parallel with that of the main machine. This third method seems to be by far the most practical, where low temperatures are desirable, for not only can as low or lower temperatures be obtained by this method as by either of the other methods, but a part of the power expended in the main engines in compressing the gas is here recovered and put to some useful purpose. The principal difficulties so far encoun-

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[a] The production of natural gasoline in California. The Bessemer Monthly, December, 1913, p. 1.

tered in dealing with the extremely low temperature obtained in this expanding cylinder, frequently as low as −50° to −60° F. (−46° to −51° C.), have been those of lubrication and obstruction due to congealed moisture. The former can usually be overcome by using a good grade of low-temperature oil and by exercising care in so feeding this oil to the cylinder and valves that it is applied directly to the surfaces in contact. The problem of removing all moisture from the gas before allowing it to enter the expanding cylinder is not, in all cases, so simple as would appear, for in spite of the fact that the temperature of this gas before expansion is several degrees below the freezing point of water, a certain amount of moisture sometimes persists in spite of all efforts to trap it out and later freezes either in the expanding cylinder or, as is more frequently the case, in the double cooling coils, necessitating the application of heat from time to time to thaw them in order that the operation may continue. To eliminate the possibility of shutdowns from this cause it has been found necessary in some cases to install double coils in duplicate, so that one half may be shut down for thawing without seriously disturbing the operation of the plant. A little warm high-pressure gas led to these coils has proved a very simple and convenient means of removing this accumulation of frost.

DETAILS OF EQUIPMENT.

With lower temperatures has come a recognition of the value and importance of thorough insulation of all piping through which this low-temperature gas is handled. This insulation is usually accomplished by boxing the coils and packing with dry sawdust, while all other piping is covered with a good grade of molded cork insulation. The finer details of construction and operation such as this were neglected during the earlier attempts at the recovery of gasoline, but their importance is now being fully recognized, and in the most up-to-date plants all condensing equipment following the water-cooling coils is housed and the piping carefully insulated.

The value of automatic traps, for handling the gasoline from the accumulators as fast as it is condensed, in order to eliminate as far as possible the solution of compressed gas in the product, is rapidly being appreciated, and at many plants the vapor tensions and evaporation losses have been materially reduced by the adoption of these simple devices.

IMPORTANCE OF WATER SUPPLY.

Another obstacle that the California operators have had to overcome is the difficulty of obtaining water in sufficient quantities and of such temperature as is necessary for cooling purposes. Water must be carefully conserved, for most of it is brought from some outside source and water bills form no small item in the operating expenses of a plant. This conservation has been accomplished by using the same water over and over again, pumping it through cooling towers and reducing its temperature by evaporation before leading it again over the cooling coils and through cylinder jackets. Only enough new water is added from time to time to make up for evaporation losses and those due to unavoidable leaks.

SPECIFIC GRAVITY AND PRICE OF PRODUCT.

The gravity of the product obtained varies greatly, running as low in some cases as 67° B., while in others it varies between 85° and 90° B., this gravity being the blend of all the cuts from any one plant.

The price obtained for the unblended product ran in the neighborhood of 10 cents at the plant, but some of the larger operators are doing their own blending, and marketing a resulting product at 62° B. that brings them from 15 to 17 cents, thus realizing the maximum return from the production of their plants.

THE INDUSTRY IN THE MID-CONTINENT FIELD.

DETAILS OF PRODUCTION.

In the Mid-Continent field the first plant was installed in 1909 by D. W. Franchot at Kiefer, Okla. At the close of the year 1911 there were 7 plants in operation, making about 2,000 gallons of gasoline daily. In June, 1913, there were 23 plants. Table 1, following, shows the location of some of the plants in the Mid-Continent field on June 1, 1913, the quantity of gas used, the number of wells used, the number of compressor units, the reduced pressure to which gas is subjected when drawn from the wells, the compression to which the gas is subjected in the compressors, the quantity of gasoline produced, the gravity of condensate in the accumulator tank, the purpose for which the condensate is used, the value of the plant, and the quantity of the gasoline sold. Complete returns were not obtained.

TABLE 1.—*Details of production of gasoline from natural gas in the Mid-Continent field in June, 1913.*

Location of plant.	Number of plant.	Quantity of gas used.	Number of wells connected to plant.	Number of compression units comprising plant.	Reduced pressure to which gas is subjected.	Compression to which gas is subjected.	Gravity of gasoline in accumulator.	Purpose for which gasoline is used.	Value of plant equipment.	Quantity of gasoline sold per month.
		Cubic feet per 24 hours.			*Inches of mercury.*	*Pounds per square inch.*	°*B.*			*Gallons.*
Cushing, Okla...	1	250,000	5	1	....	40 to 300	86	Gasoline gas.	....	....
Alluwee, Okla...	2	375,000	260	2	....	Up to 300	89	Blending.	$30,000	33,000
Coalton, Okla...	3	125,000	38	1	0 to 20	Up to 350	....	...do.....	....	8,000
Kiefer, Okla., Glenn pool.	4	300,000	......	1	0 to 20	Up to 300	....	...do.....	17,000	....
Do.........	5	800,000	......	4	0 to 15	25 to 50 and 275 to 350	76 to 98	...do.....	24,000	50,000
Delaware, Okla.	6	250,000	......	1	....	50 to 250	100	...do.....	40,000	45,000
Kiefer, Okla.....	7	40,000	10	......	....	30 to 40 and 300	80	...do.....	6,000	4,000
Near Muskogee, Okla.	8	40,000	5	1	16	50 to 55 and 250 to 300	100	...do.....	11,000	3,000
Do.........	9	70,000	......	1	25	40 and 250	88	...do.....	5,500	4,500
Near Kiefer, Okla., Glenn pool, No. 1 plant.	10	250,000	36	1	0 to 20	30 to 40 and 175 to 300	98	...do.....	11,000	3,700
Near Muskogee, Okla., plant No. 6.	11	200,000	11	1	0 to 20	30 to 40 and 175 to 300	94	...do.....	10,000	19,000
Near Kiefer, Okla., Glenn pool.	12	150,000	9	1	....	30 and 250	87	...do.....	12,000	18,000
Near Kiefer, Okla.	13	170,000	......	1	....	30 and 300	78	...do.....	10,000	10,000

QUANTITY AND VALUE OF CONDENSATE.

These plants, with others in Oklahoma not listed in the foregoing table, produced about 350,000 gallons of natural-gas condensate during April. The value of the condensate is estimated at $35,000, about 500 wells being utilized. At the close of May, 1913, there were in Oklahoma 25,612 producing oil wells, making about 4,000,000 barrels of oil, worth $3,520,000, at 88 cents a barrel, the price then prevailing. If the average percentage of gasoline obtainable from Oklahoma crude oil by refining is estimated to be 14, then 23,520,000 gallons of gasoline could be produced, which, at the rate of 15 cents per gallon, would be worth $3,528,000.

Gas from about 2 per cent of the total oil wells was used for making gasoline. The gasoline made from casing-head gas was probably less than 1 per cent of the gasoline produced at the refinery.

At the end of the year 1913 there were 40 plants in operation in Oklahoma. The value of gasoline produced in 1913 was $577,944.[a]

FUTURE OF THE INDUSTRY IN OKLAHOMA.

It has been stated that about 25,000 producing wells were in operation on the last day of May, 1913, and that 500 were used for gasoline production. It is not to be inferred that all of these wells will contain gas of sufficient volume or proper character to produce gasoline.

Probably less than one-third of the total number of wells will be available, owing to the reasons following. These reasons also apply of course to other localities in the United States.

(1) Insufficient gas yield.

(2) Unfavorable location of wells with reference to transportation of finished product.

(3) Poor quality of gas.

On the other hand, gas from many wells that have not been utilized as yet will produce gasoline in paying quantities. Many wells that do not produce gas of proper character now will do so in the future as the wells grow older. This statement is substantiated by the experience of many operators in the Appalachian fields. There the old wells are producing gas that is the richest in gasoline vapors. The final maximum yield per 1,000 cubic feet of gas will be reached when the minimum pressure is reached in the oil well. The gasoline yield should then become practically constant.

The Muskogee, Okmulgee, Cushing, and Cleveland oil fields in Oklahoma possess many wells that are promising. The outlook for large producing wells in the north of the State is not so promising. Seemingly there is not enough gas in many territories to warrant the installation of gasoline plants. There are, however, many favorable locations, and to date those plants that have been developed in the northern region are profitable notwithstanding the small size and great number of wells connected.

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[a] Hill, B., Natural gas: Mineral Resources U. S. for 1913: U. S. Geol. Survey, 1914, p. 1481.

DEVELOPMENT OF INDUSTRY IN FOREIGN COUNTRIES.

Development of the industry in foreign countries has been slow. The authors have knowledge of one plant at Payta, Peru, installed by Americans. The plant handles 60,000 cubic feet of gas per day. Another small plant in the Galicia oil fields, Austria-Hungary, handled 20,000 cubic feet of gas per day.

TOTAL GASOLINE PRODUCTION IN THE UNITED STATES.

PRODUCTION IN 1911 AND 1912.

The following table, covering gasoline production in the United States for 1911 and 1912, is taken from data compiled by Hill:[a]

The production of gasoline from natural gas in 1911 and 1912 in the United States.

State.	Number of operators.		Number of plants in operation.		Production.	
	1911	1912	1911	1912	1911	1912
					Gallons.	*Gallons.*
West Virginia	47	66	72	97	3,660,165	5,318,136
Pennsylvania	43	69	50	83	1,467,043	2,041,109
Ohio	26	25	39	43	1,678,985	1,718,719
Oklahoma	8	11	8	13	388,058	1,575,644
California	8	7	7	7	231,588	1,040,695
Illinois		4		4		386,876
Colorado		2		2		
New York		1		1		
Kentucky	....	(b)	....	(b)	....	....
Total	132	185	176	250	7,425,839	12,081,179

PRODUCTION IN 1913.

The data following show the production of gasoline from natural gas for the year 1913. The figures are taken from data obtained by the United States Geological Survey.[c]

Production of gasoline from natural gas in the United States in 1913, by States.

State.	Number of operators.	Number of plants.	Yearly capacity.	Value of year's production.
			Gallons.	
West Virginia	63	115	7,662,493	$807,406
Pennsylvania	100	40	3,680,096	405,186
Ohio	25	113	2,072,687	212,404
Oklahoma	19	40	6,462,968	577,944
California	12	14	3,460,747	376,227
Illinois	6	12	721,826	79,276
Colorado	2	2		
New York	3	3		
Kentucky	1	(b)		
Kansas	1	1		
Total	232	....	24,060,817	2,458,443

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[a] Hill, B., Natural gas: Mineral Resources U. S. for 1913, U. S. Geol. Survey, 1914, pp. 1479–1480.

[b] Natural condensation in the pipes.

[c] Hill, B., Op. cit.

According to these figures the increase in the production of gasoline from natural gas in the United States for the year 1913 over the year 1912 was about 100 per cent. According to the United States Geological Survey figures, the rate of increase for 1912 over 1911 was 63 per cent.

According to Hill, the total estimated consumption of natural gas in the United States in 1912 was 562,203,452,000 cubic feet,[a] and the total quantity used for making gasoline was 4,687,796,329.[b] This latter figure represents gas not included in the total consumption, for it covered gas principally going to waste. At the close of the year 1913,[b] this figure was 9,899,441,500 cubic feet and the total quantity of gas used for all purposes was 581,898,239 cubic feet.[a] The percentage of natural gas used for making gasoline was 1.7.

CHEMISTRY OF NATURAL GAS.

In the gasoline industry natural gas is popularly classified in two great divisions—"wet" gas and "dry" gas. Gas not intimately associated with oil is known as "dry" gas; that in the same stratum with oil and in intimate contact with it is the so-called "wet" gas, from which gasoline is condensed. As the result of many analyses, the Bureau of Mines finds that natural gas is a mixture in which the hydrocarbons of the paraffin series predominate and that small proportions of nitrogen, carbon dioxide, and water vapor are present. In a few samples of natural gas the bureau has found that the carbon dioxide may amount to as much as 10 per cent; in one sample it amounted to 31 per cent. Another natural gas examined contained 97.9 per cent of nitrogen, 0.10 per cent of carbon dioxide, and 2 per cent of methane. Hence the proportions of carbon dioxide and nitrogen may in exceptional samples be large.

Carbon monoxide, hydrogen, hydrocarbons of the olefin series, or other gases that most textbooks state are constituents of natural gas are not present. Hydrogen sulphide is found in some natural gas.

NATURAL-GAS ANALYSES MADE BY THE BUREAU.

The results of some natural-gas analyses made by the bureau are shown in Table 2, following. They are given to show the variation in composition of different samples of natural gas:

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[a] Hill, B., Natural gas: Mineral Resources U. S. for 1913, Geol. Survey, 1914, p. 1414.

[b] Hill, B., op. cit., p. 1480.

TABLE 2. —*Results of analysis of samples of natural gas.*

[* Indicates that notes following table contain additional information regarding sample.]

Lab. No.	Date of sampling.	Oil fields.	County.	State.	Location.	Oil company holding lease.	CO_2.	O_2.	N_2.	Total paraffins.	Total.	CH_4.	C_2H_6.	Gross heating value per cubic foot, 0° C, 760 mm.	Specific gravity (air=1).
														B. t. u.	
9206	August, 1909	Santa Maria	Santa Barbara	Cal.	T. 9 N., R. 34 W.	Santa Maria Oil & Gas.	15.5	0.2	1.4	82.9	100.0	62.7	20.2	1,044	0.81
10576	February, 1910	Torrey	Ventura	do		Torrey	6.8	.0	3.4	89.8	100.0	54.2	35.6	1,240	.81
10579	June, 1910	Coalinga	Fresno	do	Sec. 25, T. 20 S., R. 15 E.	Kern Trading & Oil.	11.1	.0	.9	88.0	100.0	88.0	.0	937	.66
10000	September, 1909	McKittrick	Kings	do	Sec. 29, T. 30 S., R. 22 E.	Dabney	30.4	.0	2.4	67.2	100.0	66.2	1.0	724	.85
9210	July, 1909	West Los Angeles	Los Angeles	do		Pacific Petroleum	1.0	.1	5.2	93.7	100.0	91.0	2.7	1,019	.60
9213	do	Sunset	Kings	do	Sec. 31, T. 31 S., R. 23 E.	Crandall	10.5	.0	1.8	87.7	100.0	87.7	.0	934	.66
9211	do	Fullerton	Orange	do	Sec. 8, T. 3 S., R. 9 W.	C. V. Hall	1.7	.0	2.1	96.2	100.0	86.7	9.5	1,100	.63
10577	November, 1909	Kern River	Kern	do	Sec. 32, T. 28 S., R. 28 E.	Associated	6.5	.0	1.2	92.3	100.0	84.3	8.0	1,047	.66
*1871	September, 1911		Clarion	Pa.	Near town of Mill Creek.		.0	.0	1.1	98.9	100.0	96.4	2.5	1,073	.57
*1889	do		Forest	do	3 miles east of Nebraska.		.0	.0	1.0	99.0	100.0	70.8	28.2	1,279	.70
*1872	February, 1911		Clarion	do	Near Mill Creek	South Penn Oil	.0	.0	1.7	98.3	100.0	80.5	17.8	1,189	.65
*1848	September, 1911		Butler	do	Concord Township, near Chicora.		.0	.0	.9	99.1	100.0	53.3	45.8	1,420	.78
*1838	do		Armstrong	do	6 miles from Bradford.		.05	.0	1.45	98.5	100.0	81.6	16.9	1,184	.64
*3177	December, 1912	Hogshooter	Osage	Okla.	North end of Hogshooter field.		1.1	.0	4.6	94.3	100.0	94.3	.0	1,004	.58
*2121	February, 1912		Creek	do	Kiefer	D. W. Franchot	2.4	.0	1.8	95.8	100.0	64.1	31.7	1,273	.74
*2445	March, 1912		Barren	Ky.	5 miles from Glasgow.	Oskamp Development.	2.5	.0	1.3	93.3	[a]100.0	23.6	69.7	1,548	.91
*2444	do		do	do	do	do	2.6	.0	5.1	92.3	[b]100.0	44.1	48.2	1,367	.84
*1031	September, 1910		Grand	Utah.	Moab		3.6	.0	5.6	90.8	100.0	90.8	.0	967	.61
*1033	do		do	do	do		3.5	.0	6.5	90.0	100.0	90.0	.0	959	.62

[a] H_2S, 2.9 per cent.

[b] H_2S, 0.1 per cent.

TABLE 2.—*Results of analysis of samples of natural gas*—Continued.

Lab. No.	Date of sampling.	Oil fields.	County.	State.	Location.	Oil company holding lease.	CO_2.	O_2.	N_2.	Total paraffins.	Total.	CH_4.	C_2H_6.	Gross heating value per cubic foot, 0° C, 760 mm.	Specific gravity (air=1).
														B. t. u.	
*1063	September, 1910			Oreg.	Sec. 26, T. 8 N., R. 10 W.		3.0	0.0	0.9	96.1	100.0	96.1	0.0	1,023	0.58
*1893	September, 1911		Crawford	Pa.	Titusville	Atlantic Refining	.0	.0	2.3	97.7	100.0	6.6	91.1	1,765	.99
1065	September, 1910						.5	.0	12.5	87.0	100.0	87.0	.0	927	.60
*1066	do		Tillamook	Oreg.	5½ miles southeast of Tillamook, sec. 10, T. 2 S., R. 9 W.		.1	.0	97.9	2.0	100.0	2.0	.0	21	.96
*1378	do		Churchill	Nev.	Near Stillwater		1.3	.0	3.1	95.6	100.0	95.6	.0	1,018	.58
5101	July, 1914		Cuyahoga	Ohio.	Cleveland		.0	.0	1.3	98.7	100.0	80.5	18.2	1,196	.65
4982	February, 1914		Franklin	Ohio.	Columbus		.0	.0	1.5	98.5	100.0	80.4	18.1	1,193	.65
5269	March, 1914		Hamilton	Ohio.	Cincinnati		.0	.0	.7	99.2	100.0	79.8	19.5	1,213	.65
5277	April, 1914		Erie	N.Y.	Buffalo		.0	.0	4.9	95.1	100.0	79.9	15.2	1,134	.65
5588	November, 1914		Jasper	Mo.	Joplin		.6	.0	2.5	96.9	100.0	92.6	4.3	1,066	.59
5590	August, 1914		Jefferson	Ky.	Louisville		.0	.0	1.8	98.2	100.0	77.8	20.4	1,205	.66
5445	October, 1914		Dallas	Tex.	Dallas		.1	.0	38.4	61.5	100.0	50.6	10.9	742	.77
......	September, 1914		Nowata	Okla.	Nowata		1.3	.0	2.2	96.5	100.0	96.5	.0	1,038	.58

NOTES.

Sample 1871.—The gas sampled comes from the fourth sand, which is 800 feet deep. The rock pressure in the well was 300 pounds per square inch. The capacity of the well was 3,000 cubic feet of gas per day.

Sample 1889.—The sample came from the third sand. Five gas wells were tapped by the pipe line from which the gas sample was drawn. The rock pressure at the wells was 62 pounds per square inch.

Sample 1872.—Collected in Clarion County, Pa., near the town of Mill Creek. The sample came from the Bradford or Little Bradford sand, which is 2,100 feet deep. The rock pressure was 850 pounds per square inch and the capacity of the well 3,000,000 cubic feet a day. This gas contains a higher percentage of the heavier paraffin hydrocarbons than does the gas represented by sample 1871 that comes from the shallower sand.

Sample 1848.—The sample was collected at well No. 14 of the A. W. Starr farm. The gas is from the Speechley sand.

Sample 1838.—The sample was collected from the No. 1 well on the J. S. Somerville farm. The gas comes from the fourth sand.

Sample 3177.—The sample was taken from the Collinsville pipe line in the pumping station of the Kansas Natural Gas Co. at the north end of the Hogshooter field. This line tapped about 40 gas wells. The initial rock pressure of the wells was 490 pounds per square inch. At the date of collection of the sample the pressure had dropped to 120 pounds. This was one of the few samples of natural gas analyzed by the bureau that contained only methane as the combustible constituent when the sample came from a sand in close proximity to sands producing oil. Most gas from the oil regions contains other paraffin hydrocarbons besides methane, and gas coming from the same sand as the oil invariably contains other paraffin hydrocarbons. It is difficult to explain the presence of an enormous quantity of methane gas, such as is contained or was contained in the Hogshooter pool, in close proximity to oil sands. If gas and oil were of common origin in the particular region, one would suppose that the Hogshooter gas should contain higher members of the paraffin hydrocarbons than methane, as do the gases from neighboring oil wells. The phenomenon might be connected in some way with the movement of the gas through strata whereby ethane and still higher paraffin hydrocarbons were separated.

Sample 2121.—The sample represented a casing-head gas from the Glenn sand. It was collected about 2,000 feet east of the railroad station at Kiefer, Okla.

Sample 2445.—The sample was collected at the Cully well on the Ellis farm. The well was 340 feet deep and was drilled in 1903. A large amount of hydrogen sulphide was present in the sample. The determination of the hydrogen sulphide was made by absorbing the H_2S in a standard iodine solution and titrating with a standard sodium thiosulphate solution. Other sulphur compounds may have been present; hence the assumption that 2.9 per cent was all H_2S may be wrong. The gas possessed the odor of H_2S.

Sample 2444.—The sample was obtained in the same locality as sample 2445, but from a different well. The well was 280 feet deep. Both wells were drilled in 1903. The hydrogen sulphide content of this sample is much smaller than that of sample 2445.

Sample 1031.—The sample is classified as a marsh gas in distinction from those gases that are found in the oil field and contain appreciable quantities of the higher paraffin hydrocarbons.

Sample 1033.—The sample was collected at a near-by seepage in the same locality. The gas was simply bubbling up through marshy ground.

Sample 1063.—The sample was collected from a slough on the Brown farm. It also represented a marsh gas.

Sample 1893.—The sample was collected from 15 oil wells, Nos. 1 to 15, of the Atlantic Refining Co. (South Penn Oil Co.).

Sample 1066.—The striking feature of this sample is the high percentage of nitrogen. A well had been drilled and the gas was issuing from it in considerable quantity. For present purposes to which natural gas is put, the gas would of course be worthless.

Sample 1378.—The sample was collected from a slough about 15 feet in diameter. It represented what was seemingly another marsh gas.

The last eight samples given in the table were taken from natural gas supplied the city in which the sample was obtained.

COMMENTS ON THE ANALYSES.

It will be observed that the samples ranged in heating value from 724 to 1,657 British thermal units per cubic foot at 0° C. and 760 mm. normal pressure, except one sample which had the abnormally low heating value of 21 British thermal units per cubic foot.

The analytical results show only approximately the quantity of the individual hydrocarbons, although the percentages of total paraffin hydrocarbons are correct. The heating values of the samples, as calculated from the analyses, are also correct. A discussion of natural-gas analyses is found in Bulletin 42 of the Bureau of Mines.[a] The causes of erroneous results that are frequently reported are there explained.

METHOD OF ANALYSIS USED.

The ascertaining of the exact proportions of the different hydrocarbons that may be found in natural gas has long been a stumbling block in gas analysis. The ordinary eudiometric method of analysis offers little in the way of a complete separation of a natural gas into its various constituents. Determination of the total paraffin-hydrocarbon content, with an approximate determination of the individual paraffins present, has been the only end attained. The Bureau of Mines in working on this problem succeeded in separating a natural gas into its individual paraffins by means of fractional distillation at low temperatures. Natural gas was first liquefied by means of liquid air, and then separated into its constituents by fractionation in vacuum at different temperatures.

The results of a complete analysis, including the quantity of each paraffin hydrocarbon found by the above method follow. For comparison, the results of an eudiometric analysis of the natural gas of Pittsburgh are also included.

Analytical results obtained by two methods.

Constituent.	Results obtained by liquifaction and fractionation.	Results obtained by eudiometric analysis.
	Per cent.	*Per cent.*
Methane	84.7	79.2
Ethane	9.4	19.6
Propane	3.0	....
Butane (chiefly)	1.3	....
Nitrogen	1.6	1.2

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[a] Burrell, G. A., and Seibert, F. M., The sampling and examination of mine gases and natural gas, 1913, 116 pp.

Included in the nitrogen content of the above analyses is 0.03 per cent of carbon dioxide present in the natural gas. The natural gas supplied to Pittsburgh can not be used for the commercial production of gasoline, although it contains sufficient of the higher paraffin hydrocarbons, the butanes, pentanes, and hexanes, to produce some condensation (drip) in the pipe lines in the winter time. These hydrocarbons are present in small quantity, as shown by fractionation experiments conducted by the bureau. It is only because of the immense volume of gas passing through the lines that appreciable condensation of vapor occurs.

A "wet" natural gas from which gasoline is obtained commercially was also subjected to fractionation.[a] The results follow:

	Per cent.
Methane	36.8
Ethane	32.6
Propane	21.1
Butanes, pentanes, hexanes, etc	9.5
Total, including 1.00 per cent nitrogen and 0.03 per cent carbon dioxide	100.0

PROPERTIES OF THE PARAFFIN HYDROCARBONS.

The properties of those hydrocarbons of the paraffin series that concern the gasoline industry are given below:

Properties of seven paraffin hydrocarbons.

Hydrocarbon.	Formula.	Boiling point.[b]	Specific gravity (at 0° C. and 760 mm.; air=1).	Weight of 1 liter.	Heating value per cubic foot at 0° C. and 760 mm.[c]	Illuminating value.	Liquefaction point.	Calculated volume of gas (at 60° F. and 30 inches pressure) from 1 gallon.	Theoretical volume of air necessary to burn 1 cubic foot of gas.
		° C.		*Grams.*	*B.t.u.*	*British candle-power.*	*° C.* *Lbs. per sq. inch.*		*Cubic feet.*
Methane[d]	CH_4	−160	0.554	0.7159	1,065	[e] 5.0	−95.5 at 735[f] −81.8 at 807[g]	....	9.57
Ethane[d]	C_2H_6	−93	1.049	1.3567	1,861	[h] 35.0	+35 at 664[i]	53	16.72
Propane[d]	C_3H_8	−45	1.520	1.9660	2,654	[h] 53.9	+97 at 647[g]	45	23.92
Butane[d]	C_4H_{10}	1.0	2.004	2.594	3,447	....	....	37	31.10
Pentane[k]	C_5H_{12}	36.4	....	....	4,250	....	....	31	38.28
Hexane[k]	C_6H_{14}	68.9	....	....	5,012	....	....	27	....
Heptane[k]	C_7H_{16}	98.4	....	....	....	....	....	....	....

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[a] A technical paper covering in detail this method of separating gases and the results of experiments by the bureau is being prepared.

[b] Holleman, A. F., Organic chemistry, edited by A. J. Walker, 1910, p. 41.

[c] Landolt and Börnstein, Physikalisch-chemische Tabellen, 3d ed., 1905, pp. 416, 425 (J. Thomsen).

[d] Gas at ordinary temperature.

[e] Wright, L. T., Illuminating power of methane; Jour. Chem. Soc., vol. 47, 1885, p. 200.

[f] Landolt and Börnstein, Physikalisch-chemische Tabellen, 3d ed., 1905, pp. 185 (Dewar).

[g] Landolt and Börnstein, Physikalisch-chemische Tabellen, 3d ed., 1905, p. 185 (Olszewski).

[h] Frankland, P., Illuminating power of methane: Jour. Chem. Soc., vol. 47, 1885, p. 235.

[i] Landolt and Börnstein, Physikalisch-chemische Tabellen, 3d ed., 1905, p. 182 (Dewar).

[k] Liquid at ordinary temperature.

Methane, ethane, propane, and butane, as shown by the above table, are gases under ordinary atmospheric conditions. Pentane, hexane, and heptane are liquids and are the chief constituents of ordinary refinery gasoline. Of the four gases mentioned, methane is the most difficult to liquefy. At any temperature below −160° C. it becomes liquid when its pressure is 1 atmosphere. The boiling point of the liquid is −160° C. Above −160° C. greater pressures are necessary to liquefy methane, until at a temperature of −95.5° C. a pressure of 735 pounds per square inch is required. These two values are the critical temperature and the critical pressure, respectively, for methane. No matter what the pressure applied to the gas methane, it can not be liquefied at a temperature higher than −95.5° C. The above general statement holds true for all gases. They can be liquefied at atmospheric pressure if the temperature is lowered sufficiently, but great pressure will not accomplish the liquefaction until the critical temperature is reached. Ethane (critical temperature, 35° C.; critical pressure, 664 pounds per square inch), it will be observed, is more easily liquefied and in the liquid condition has a higher boiling point (−93° C.) than methane.

Propane (critical temperature, 97° C.; critical pressure, 647 pounds per square inch) is more easily liquefied than methane or ethane.

Butane, the critical constants of which have not been determined, must be still more easily liquefied than the three already mentioned, because in the liquid condition it boils at 1° C.

OCCURRENCE OF GASOLINE IN CASING-HEAD GAS.

When a gas bubbles through or comes in contact with a liquid, it takes up and carries along vapor or minute particles from that liquid. The proportion of vapor increases as the temperature rises, and is quite independent of the nature of the gas as long as no chemical action takes place. When a natural gas in the earth comes in contact with petroleum, those fractions of the petroleum having the lower boiling points are principally taken up, inasmuch as their vapor pressures are much higher than those of the other fractions. If the well is under reduced pressure, products with higher boiling points will also be removed in the gas. The vapors are carried with the gases mentioned, in the same manner that water vapor exists in air.

At any particular temperature a fixed quantity of water vapor will be found in the atmosphere if the latter has reached complete saturation, a condition that seldom prevails. Usually a limited supply of water has been encountered by the air, and the atmosphere is spoken of as having a certain relative humidity, meaning that the saturation is incomplete at the existing temperature, or that more water vapor could exist in the air were a source of moisture available. In a similar manner gases in an oil well mix with heavy hydrocarbon vapors. The amount of vapor carried will depend on the temperature and pressure existing in the earth, on the readiness with which the vapors can be obtained, and on the gasoline content of the crude oil in the well. A certain maximum quantity of the heavy vapors will issue with the gases from a well under given conditions of temperature and pressure. The intimateness of contact between the oil and the gas is an important factor. The maximum content, or condition of complete saturation, is probably by no means generally prevalent. The porosity or closeness of the strata, the depth of the well, and the rapid expansion of the gas from the casing head cause variations in the temperature of the gas. The pronounced temperature effects, of course, appreciably change the capacity of the gas to hold gasoline vapor. Such rapid expansion of gas from a casing head may occur as to cause a heavy condensation of vapor at the casing head, owing to a lowering of the temperature of the gas.

At some operations, wells have been under reduced pressure for a long time, so long, in fact, that only small quantities of the four permanent gases already mentioned are left in the strata. Under such conditions the mixture that comes from the well may consist almost wholly of vapors of the liquid hydrocarbons, unless air has been drawn into the strata, owing to the reduced pressure.

RELATION OF CHARACTER OF OILS IN THE SAND.

The yield of gasoline from natural gas is largely determined by the proportion of the vapor of the liquid paraffins in the gas mixture. Therefore the character of the oils in a sand is of importance.

Crude oil (petroleum) is a mixture of closely related complex hydrocarbons and of various other organic substances. There are many different compounds (isomers) corresponding to a particular molecular weight, and the boiling points of these isomers lie so closely together that their separation by fractional distillation is impossible. The liquid hydrocarbons that mainly concern the gasoline industry are the petanes, hexanes, and heptanes. However, small quantities of even higher homologues are undoubtedly obtained.

Some information as to the gasoline content of a natural gas can be gained by determining the proportion of light constituents in the oil with which the gas is associated.

Many investigations have shown that the gasoline constituents for many oils range from zero to 30 or more per cent of the total volume of the oil. Consequently, many oils are so heavy and their vapor pressures so low at existing earth temperatures that the proportion of vapors to be derived from them is too small to warrant the installation of a plant.

The table following shows the vapor pressures of the liquid paraffin hydrocarbons at various temperatures.

Vapor pressures and boiling points of the liquid paraffin hydrocarbons.

Hydrocarbon.	Vapor pressure.[a]				
	0° C.	10° C.	20° C.	30° C.	Boiling point (° C.).
Normal pentane	183.3	281.8	420.2	610.9	37.0
Normal hexane	45.5	75.0	120.2	185.4	69.0
Normal heptane	11.5	20.5	35.5	58.4	98.4
Normal octane	2.9	5.6	10.5	18.4	125.5

[a] Millimeters of mercury.

From the table it may be inferred that the chief liquid constituents of gasoline made from natural gas are the pentanes and the hexanes as their vapor pressures at any temperature are far greater than those of the other liquid hydrocarbons.

EFFECT OF PRESSURE AND TEMPERATURE ON GASES IN THE STRATA.

Natural gases in the oil fields of the United States are principally mixtures of methane, ethane, propane, and butane. Methane is always present in a well in the gaseous condition. Ethane becomes a liquid at a temperature of 35° C. under a pressure of 664 pounds to the square inch. Hence if a natural gas consisted of ethane only and was subjected to a pressure in the earth greater than 664 pounds, it would be in the liquid condition.

The authors have no evidence that ethane occurs in anywhere near the pure condition in the earth. As the proportion of ethane in a mixture decreases, there is required a proportionally greater pressure than 664 pounds to liquefy it. If a sample contained 50 per cent ethane and 50 per cent methane, there would be required a pressure of at least twice 664 pounds, or 1,328 pounds, to liquefy the ethane at 35° C., and to liquefy the methane a pressure of at least twice 735 pounds, or 1,470 pounds, at −95.5° C. Moreover, a temperature of −95.5° C. is far below that prevailing in oil and gas sands. A pressure of 1,328 pounds per square inch is probably unknown in the gas fields, but pressures as high as 800 to 1,000 pounds have been measured. Propane and butane are each more easily liquefied than ethane.

The critical temperature of propane is 97° C., and its critical pressure is 647 pounds per square inch. According to analyses made by the authors the amount of propane in most natural gases is less than that of ethane, so pressures sufficient for its liquefaction do not exist in the sands penetrated by wells.

The natural gas of Pittsburgh, according to liquefaction experiments made by the authors, contains about 84.7 per cent methane, 9.4 per cent ethane, 3.0 per cent propane, 1.3 per cent butane, (chiefly), and 1.6 per cent nitrogen. To liquefy the methane in this mixture at a temperature of −95.5° C. would require a pressure of at least $\left(\frac{100}{84.7}\right)$ 735, or 868 pounds. To liquefy the ethane at 35° C. there would be required a pressure of $\left(\frac{100}{9.4}\right)$ 664, or 7,064 pounds, and to liquefy the propane at 22° C. there would be required a pressure of $\left(\frac{100}{3.0}\right)$ 132.3, or 4,410 pounds. It will be noted that the critical temperature of methane is so low that under no condition could one conceive of its being liquefied in the earth. The critical temperature of ethane is a temperature that prevails in some rock strata, but the amount of ethane present in natural gas is invariably so small that pressures much higher than those found in rock strata would be required to liquefy the ethane.

As the temperature of a gas is lowered from its critical temperature, less pressure is required to liquefy it until finally at a certain temperature it becomes liquid at ordinary pressures. Propane has a critical temperature of 97° C. This temperature is higher than that ordinarily found in the sands of oil or gas fields, where a thermal gradient of 1° C. for each 60 or 70 feet of depth may be assumed. The temperature has to be −45° C. at ordinary pressures, however, for liquefaction to occur. Such a temperature is much lower than rock-strata temperatures. At 22° C. there is required a pressure of 4,410 pounds.

It follows that temperatures found in rock strata are not low enough, that rock pressures are not high enough, and that the amount of propane in natural gases is too small to allow the existence of liquid propane in the sands penetrated by wells.

Butane gas becomes liquid at 1° C. at a pressure of 1 atmosphere. Its critical constants have not been determined, so far as the authors are aware. Its liquefaction point at ordinary pressures (15 pounds per square inch) is much closer to normal temperature than the liquefaction points of the three paraffin hydrocarbon gases already mentioned. Hence, if it constituted the whole of a natural gas, one could easily conceive that it would occur in the earth in the liquid condition. But in many natural-gas mixtures it appears to be present in even less amount than the other three gases. In Pittsburgh natural gas it is present in a proportion equal to about 1.3 per cent. With this quantity present, it would require a pressure of 1,077 pounds per square inch at 1° C. for liquefaction. At the higher temperatures of gas sands greater pressures would be required. If present to the extent of 20 per cent there would be required a pressure of 75 pounds at 1° C., and if it constituted 50 per cent of a gas a pressure of 30 pounds would be required. Gases that are used for the condensation of gasoline usually issue from the earth either under reduced pressure, atmospheric pressure, or just above atmospheric pressure. In exceptional instances the pressure may be 50 or even 100 pounds, but at most plants the gas used issues from the wells under reduced pressure. In those gases that are used for gasoline condensation, butane, and also propane and ethane, are found to be present in greater proportions than in the so-called "dry" gases that issue under much pressure and are so largely used for heating and lighting towns. The authors believe that butane may be present in the "wet" gases to the extent of 10 per cent. Hence one can conceive that the amount of butane may be high enough, also the rock pressures high enough and the earth temperature low enough, so that in some sands butane may be present in the liquid condition. But if reduced pressures prevail in wells, as in most wells used for gasoline condensation, the rock pressures are usually too low, even if the partial pressure of the butane in the gas mixture is high, to permit liquefaction to take place.

In summarizing, one may say that at those wells from which gas is drawn for gasoline condensation, the three gases, methane, ethane, and propane, invariably occur in the earth in the gaseous condition. Butane probably occurs as a gas in some places, but in others it is present as a liquid.

The question has been raised frequently as to whether natural gases are not accumulated as liquids in the underground reservoirs. If such were the case it would be possible for a single, comparatively small subterranean reservoir to yield for many years much larger quantities of gas than such reservoirs do yield.

As regards Pittsburgh natural gas and other similar gases that issue under considerable pressure from strata, none of the gaseous constituents present is liquid in the earth. However, where gases are associated with petroleum in the same strata, under heavy pressures, there is considerable solution of the gases in the oil. The natural gas used in Pittsburgh is not associated with oil in the earth.

TESTING NATURAL GASES FOR GASOLINE CONTENT.

Before plants are erected for the purpose of extracting gasoline from natural gas the yield and quality of the gas should be thoroughly investigated. Also of much importance is the marketing of the gasoline.

CLASSIFICATION OF KINDS OF NATURAL GAS.

As stated before, as regards the making of gasoline, natural gas is popularly classified in two divisions—"wet" gas and "dry" gas. This classification has come largely into general use with the development of the gasoline industry. Between the two classes there is no sharp line of demarcation.

"DRY" NATURAL GAS.

Some natural gas contains only methane as the combustible constituent and according to the above classification may be considered the driest of natural gases. This kind of gas is rare in the oil fields, but is common in gas fields, or in marshy districts unassociated with oil. The Hogshooter pool of Oklahoma, according to tests made by the bureau, produces a natural gas that contains methane as the only combustible constituent.

This kind of gas is found in States or districts in which oil has never been found. Incidentally it might be mentioned that the occurrence of such gas naturally escaping from the surface of the earth affords some proof of the nonexistence of oil. However, the indication is not infallible, because some natural gas that contains only methane as the combustible constituent is found in the oil fields. This gas comes from sands that do not bear oil.

The next grade in the transition of "dry" to "wet" gas may be considered that at present obtained from the Appalachian oil fields and used in Pittsburgh, Pa., and other cities. This natural gas issues under considerable pressure from wells in or near the oil fields. It has varied little in composition from the figures given on page 24 for the three years that the Bureau of Mines has been testing it. Air has never been detected in the samples tested. Many wells are abandoned yearly by the company that furnishes the city the supply, and new wells are drawn upon, the wells being abandoned when the rock pressure becomes so low as to be insufficient to assist in forcing the gas to Pittsburgh and other points of consumption, or when the yield becomes too small even with the gas pumps that are used. In composition this gas is typical of the natural gas supplied to many cities. All of the ingredients present are gases at ordinary temperatures. Traces of butane and even of higher paraffin hydrocarbons are present—enough because of the many thousands of cubic feet of gas transported daily, especially in the winter time, to cause some condensation of vapors or drip, in the pipe lines. This gas has been said to pass at the rate of a mile a minute through mains connecting the wells to Pittsburgh. The drip is not sufficient to indicate that the gas is of value for gasoline extraction.

"WET" NATURAL GAS.

As to the so-called "wet" gas, or that from which gasoline can be extracted in quantity sufficient to warrant the installation of a plant, the proper testing of such gas in order to determine its gasoline content is of much importance. In the early days of the gasoline industry some failures of plants to fulfill expectations were due to inadequate testing of the gas before the construction of the plant had begun.

METHODS AND EQUIPMENT USED IN TESTS.

At present, tests have become better standardized, and there is scarcely any excuse for the failure of a plant because of inadequate preliminary tests. By itself, the ordinary eudiometric analysis is of little value for determining the gasoline content of natural gas. Moreover, it is extremely difficult to make, and the authors are safe in saying that a gas analyst must have had experience in refined analytical methods before he can make a satisfactory analysis of natural gas, especially of "wet" gas. In addition, the ordinary gas-analysis determination informs one only of the two predominating paraffins present but gives slight knowledge of the quantity of gasoline vapors. Early in the history of the industry, gas analysts turned their attention to other more easily conducted and more definite tests. Those laboratory methods adopted and at present in chief use have to do with solubility and specific-gravity tests.

SOLUBILITY TESTS.

Natural gases are soluble in various solvents, such as alcohol, claroline oil, olive oil, kerosene, sperm oil, and rape-seed oil, in proportions depending upon the amount of higher paraffin hydrocarbons present in the gas mixture. All of the solvents mentioned have been used. F. P. Peterson, of Tulsa, Okla., informed the authors that he found it expedient to use claroline oil.

USE OF CLAROLINE OIL.

The Bureau of Mines methods of testing are described in Bulletin 42[a] of the bureau. In using claroline oil the following procedure is adopted: 35 c. c. of the oil is placed over mercury in an ordinary Hempel gas pipette, and 100 c. c. of the natural gas to be tested is shaken with the oil until no further absorption of the gas mixture occurs. It was found that many natural gases from which gasoline is at present commercially obtained were soluble in the oil to the extent of 30 to 86 per cent of their volume.

In figure 1 is shown a gas-analysis apparatus for determining the solubility of natural gas in claroline oil or alcohol. It consists of a measuring burette, *e*, having a capacity of 100 c. c., and an absorption pipette, *c*. It is provided at the top with a three-way T stopcock, *d*, so that communication can be made between the burette and outside air, or between the burette and the pipette. Water is used in the burette and mercury in the pipette. To begin an analysis, 35 c. c. of claroline oil or 50 c. c. of alcohol is placed in the pipette *c* over the mercury. A 100-c. c. part of the gas sample is then drawn into the burette, measured, and forced into the pipette *c*. The pipette *c* is shaken for about three minutes to thoroughly mix the oil or alcohol and gas. The gas is then transferred to the burette and measured, and the loss in volume is noted. The gas is again passed into the pipette and the shaking operation repeated. Finally the gas is measured again in the burette. The first and second readings should agree within 0.50 per cent. If they do not, the operation should be repeated until the burette readings become constant.

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[a] Burrell, G. A., The sampling and examination of mine gases and natural gas, 1913, 116 pp., 2 pls., 23 figs.

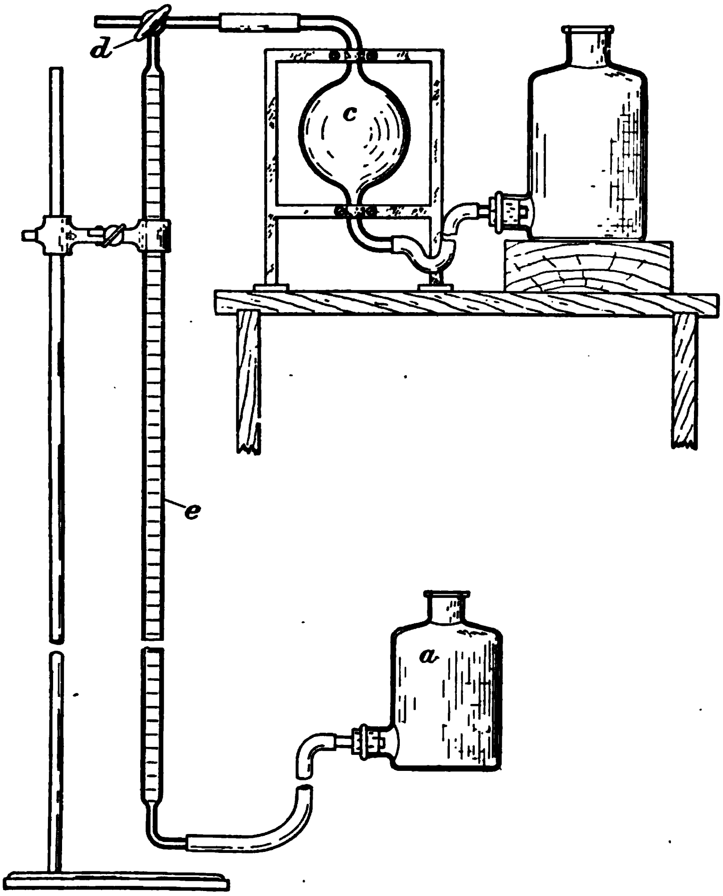

FIGURE 1.—Apparatus for determining the gasoline content of natural gas.

Below are given tables showing the solubility of natural gas and of methane and ethane in different oils. A 35-c. c. sample of the oil was shaken with 100 c. c. of the gas until absorption of gas by the oil ceased.

Solubility in different oils of the natural gas used at Pittsburgh.

Kind of oil used as solvent.	Character of oil.	Solubility of gas.
		Per cent.
Claroline	Mineral	15.5
Russian white (kerosene)	do	16.4
Sperm	Animal	16.5
Olive	Vegetable	13.7
Rapeseed	do	14.7
Cottonseed	do	14.8

It was possible to check the above determinations within 0.50 per cent. Considerable uniformity as regards the solubility of the natural gas in the different oils will be noticed. The claroline oil used had the following characteristics, as determined by I. C. Allen, chemist of the bureau:

Characteristics of claroline oil.

Specific gravity	0.8667 at 15° C.
Viscosity	4.4° Engler at 20° C.
Flash point	152° C., Pensky-Martens closed test.
Ignition point	270° C., Pensky-Martens closed test.

Solubility of pure methane in claroline and cottonseed oils.

Oil.	Character of oil.	Solubility of methane.
		Per cent.
Claroline	Mineral	11.0
Cottonseed	Vegetable	9.5

The solubility of pure ethane in claroline oil, as determined by the authors, was 68.5 per cent.

USE OF ALCOHOL AS A SOLVENT.

The Bureau of Mines has used ethyl alcohol in much the same manner that claroline oil is used for testing natural gas. Instead of 35 c. c. of the claroline oil, 50 c. c. of ethyl alcohol may be used. The procedure otherwise is exactly the same. The results obtained with alcohol are similar to those with claroline oil.

ORSAT APPARATUS FOR DETERMINATION OF CARBON DIOXIDE AND OXYGEN.

In figure 2 is shown an Orsat apparatus for the determination of carbon dioxide and oxygen in natural gas. The Orsat apparatus is so well known that it needs little description. It is sufficient to say that the burette has a capacity of 100 c. c. The pipette *b* contains caustic potash solution for the removal of carbon dioxide, and the pipette *a* contains alkaline pyrogallate solution for the removal of oxygen. The figure (fig. 2) shows the level bottle of the burette, the water jacket, and a three-way stopcock, *c*. This apparatus may be used to advantage for examining natural gases to determine whether air has leaked into mains, owing to the reduced pressures that are maintained in pipe lines at some gasoline plants.

SPECIFIC-GRAVITY TESTS.

Natural gas may vary in specific gravity from about 0.56 (air = 1) to as much as 1.65, or from a gas containing methane only as the paraffin hydrocarbon in proportions approaching 99 per cent or more of the total to an extremely "wet" gas, from which gasoline in quantities up to 4 or 5 gallons per 1,000 cubic feet can be obtained. Specific-gravity tests may be made either by weighing the gas in a small glass vessel or by means of Bunsen's effusion method. The weighing method is the more accurate. The following procedure is adopted by the Bureau of Mines:

A 100-c. c. glass globe, equipped with a stopcock, is exhausted of its contained air, thoroughly dried, and weighed. Natural gas is then introduced and a second weighing made. This weight as compared to that of an equal volume of air at the same temperature gives the specific gravity.

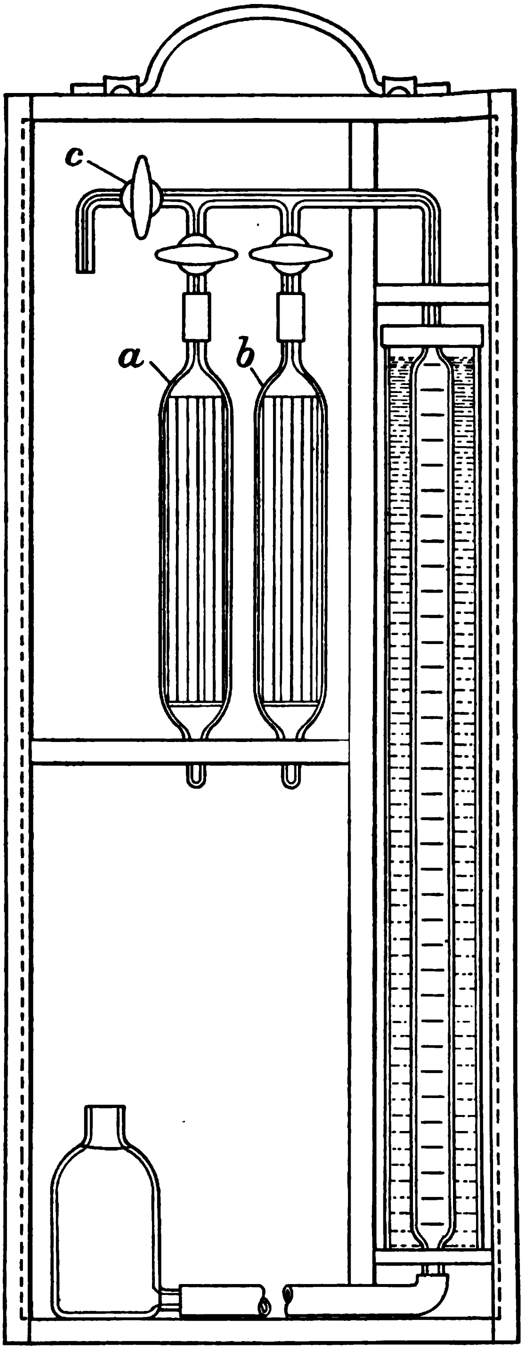

FIGURE 2.—Orsat apparatus for determining carbon dioxide and oxygen in natural gas.

EFFUSION METHOD.

In using the Bunsen effusion method, specific gravities are determined by noting the rate at which a certain volume of the gas passes through a small orifice. The rate at which a like volume of air passes through the orifice is also determined. The specific gravities of the natural gas and air are then in inverse ratio to the squares of the rates of effusion.

Some natural gas contains a large percentage of carbon dioxide. This is a heavy gas, having a specific gravity of 1.53 (air = 1). If it happened to be present in a natural gas mixture and a test were not made for it, an experimenter might be misled into believing that the gas was heavy, because of paraffin hydrocarbons present.

Many samples of natural gas contain large percentages of nitrogen. In an extreme instance the bureau found that a natural gas issuing from the earth in the State of Washington contained 98.5 per cent of nitrogen. Proportions of nitrogen as high as 10 per cent in natural gas are not uncommon. The specific gravity of nitrogen is 0.97. If much nitrogen were present an investigator might be misled by the specific-gravity test in that the test would not show the specific gravity of the paraffin hydrocarbons but the specific gravity of the entire mixture, which depends in part upon the content of nitrogen or carbon dioxide, or both.

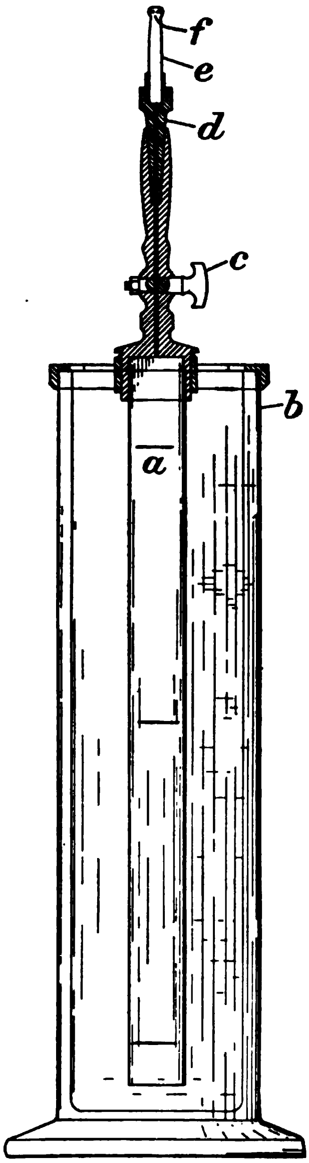

FIGURE 3.—Apparatus for determining specific gravity of gas.

CONSTRUCTION AND USE OF SCHILLING TYPE OF APPARATUS.

The authors have used the particular type of apparatus known as the Schilling (fig. 3) for the specific-gravity determination. It consists of a glass jar, *b*, with a metal top into which fits a brass column having suspended from its base a long graduated tube, *a*, and at its top a cock, *c*, and a ground-joint socket, *d*, into which sets a socket holding a small glass tip, *e*, closed at the top with a thin piece of platinum, *f*. In this platinum is a minute hole to permit the passage of gas or air at a very slow rate. All metal parts are nickeled.

The mode of operation is as follows: The glass jar is filled with water to the top graduation of the tube or to a point a little above it. The tube is then withdrawn so that it may be filled with air. The cock on the standard is then closed and the tube replaced in the jar. The cock is then opened and with a stop watch the time is taken that elapses while the water passes from the lowest graduation to the graduation above. The tube is then withdrawn and filled with gas and the procedure repeated.

The specific gravity, air being 1, is obtained by dividing the gas time squared by the air time squared. Thus, if A represents the time gas requires to pass through the orifice, and B represents the time air requires to pass through the orifice, the specific gravity of the gas will be represented by $\left(\frac{A}{B}\right)^2$.

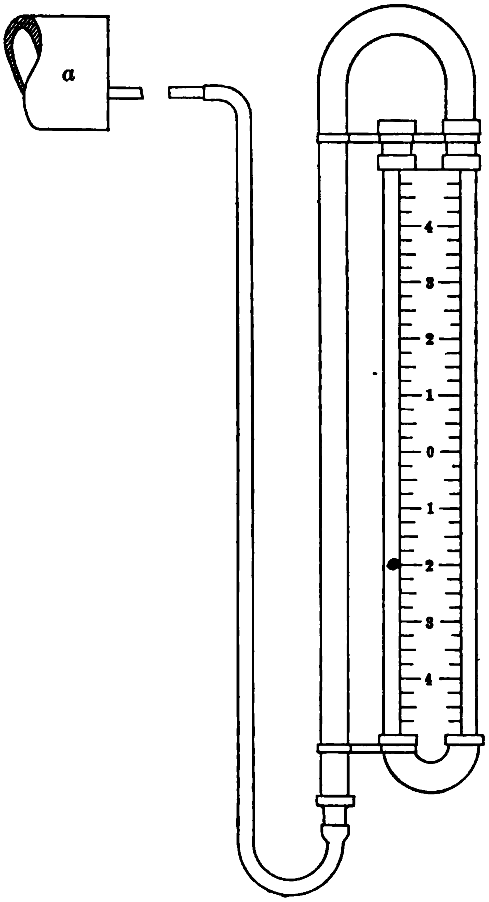

FIGURE 4.—U tube for measuring flow of gas.

USE OF THE PITOT TUBE FOR MEASURING THE OPEN FLOW OF GAS WELLS.

The quantity of natural gas that is discharged from a well is usually measured by means of a Pitot tube. (Fig. 4.) This instrument directly measures the velocity of the gas flow. In its most accurate form it consists essentially of two parts, first a tube pointing upstream for measuring the dynamic pressure and second a means of determining the static pressure. Two pressures are thus obtained. Their difference as read on a U gage gives the velocity or impact pressure of the flowing gas.

As ordinarily used for field work the static pressure of the gas flow is not obtained, the instrument consisting simply of a small tube, which is inserted in the flowing gas (*a*, fig. 4), just inside the pipe or tubing, a distance of one-fourth to one-third of the pipe's diameter from the outer edge. The plane of the opening in the tube is held at right angles to the flowing gas. At a convenient distance, varying from 1 to 2 feet, a U-shaped gage (fig. 4) is attached to the other end, which is usually half filled with water. If the gas pressure is high enough to force the water out of the tube, mercury is used, and for pressures that are so great that mercury can not be used, a spring gage is attached. A scale graduated from the center in tenths of 1 inch is placed between the two limbs of the U gage. The distance above and below this center line at which the liquid stands in the gage should be added, the object being to determine the exact distance between the high and the low side of the fluid in inches and tenths.

The top joint of tubing or casing should be free from fittings for a distance of 10 feet below the mouth of the well where the test is made. The test should not be made in a collar or gate or at the mouth of any fitting. The well should be blown off at least three hours prior to making the test, and in some cases as much as 24 hours should be allowed. After the velocity pressure of the gas flowing from the well tubing has been determined in inches of water, inches of mercury, or pounds per square inch as outlined above, the corresponding rate of flow may be ascertained from Table 3, a table prepared by F. H. Oliphant[a] and presented below. The quantities of gas stated in the table are based on a pressure of 14.65 pounds per square inch absolute, and a flowing temperature of 60° F., for a gas having a specific gravity of 0.60 (air = 1). If the specific gravity of the gas is other than 0.6 the flow should be multiplied by

$$\sqrt{\frac{0.6}{\text{specific gravity of gas.}}}$$

For flowing temperatures above and below 60° F., 1 per cent should be deducted or added for each 10 degrees.

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[a] See Wescott, H. P., Handbook of natural gas, 1913, pp. 105-106.

TABLE 3.—*Table to be used in testing gas wells with Pitot tube.*

Pressure in—			Discharge from—			
Inches of water.	Inches of mercury.	Pounds per square inch.	1-inch tubing.	2-inch tubing.	3-inch tubing.	4-inch tubing.
			Cubic feet.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
0.10	....	....	11,880	47,520	106,920	190,080
.20	....	....	17,136	68,544	154,224	274,176
.30	....	....	20,568	82,272	185,112	329,088
.40	....	....	23,520	94,080	211,680	376,320
.50	....	....	26,544	106,176	238,896	424,704
.60	....	....	29,112	116,448	262,008	465,792
.7	....	....	31,440	125,760	282,960	503,040
.8	....	....	33,624	134,496	302,616	537,984
.9	....	....	35,640	142,560	320,760	570,240
1	....	....	37,320	149,280	335,880	597,120
1.25	....	....	41,712	166,848	375,408	667,392
1.5	....	....	45,960	183,840	413,640	735,360
1.75	0.12	....	49,680	198,720	447,120	794,880
2	.147	....	53,136	212,544	478,224	850,176
2.5	.184	....	59,400	237,600	534,600	950,400
3	.22	0.108	65,088	260,352	585,792	1,041,408
3.5	.257	.126	70,272	281,088	632,448	1,124,352
4	.294	.144	75,120	300,480	676,080	1,201,920
4.5	.331	.162	79,704	318,810	717,336	1,275,264
5	.368	.18	84,000	336,000	756,000	1,344,000
6	.441	.216	92,016	368,060	828,144	1,472,256
7	.515	.252	99,360	397,440	894,240	1,589,760
8	.588	.288	106,272	425,088	956,448	1,700,352
9	.662	.324	112,656	450,624	1,013,904	1,802,496
10	.736	.36	118,800	475,200	1,069,200	1,900,800
11	.8	.396	125,160	500,640	1,126,440	2,002,560
12	.88	.432	130,128	520,512	1,171,152	2,082,048
	1.02	.5	138,960	555,840	1,250,640	2,223,360
	1.52	.75	170,280	681,120	1,532,520	2,724,480
	2.03	1.00	196,680	786,720	1,770,120	3,146,880
	2.54	1.25	219,960	879,840	1,979,640	3,519,360
	3.05	1.5	240,720	962,880	2,166,480	3,851,520
	3.56	1.75	259,920	1,039,680	2,339,280	4,158,720
	4.07	2.00	272,640	1,090,560	2,453,760	4,362,240
	4.57	2.25	294,600	1,178,400	2,651,400	4,713,600
	5.08	2.50	310,800	1,243,200	2,797,200	4,972,800
	5.59	2.75	321,000	1,284,000	2,889,000	5,136,000
	6.10	3	340,200	1,360,800	3,061,800	5,443,200
	6.61	3.25	354,120	1,416,480	3,187,080	5,665,920
	7.11	3.50	367,680	1,470,720	3,309,120	5,882,880
	7.62	3.75	380,400	1,521,600	3,423,600	6,086,400
	8.13	4.00	392,880	1,571,520	3,535,920	6.286,080
	8.64	4.25	405,000	1,620,000	3,645,000	6,480,000
	9.15	4.50	416,640	1,666,560	3,749,760	6,666,240
	9.65	4.75	428,280	1,713,120	3,854,520	6,852,480
	10.16	5.00	439,920	1,759,680	3,959,280	7,038,720
	12.20	6	476,040	1,904,160	4,284,360	7,616,640
	....	7	517,320	2,069,280	4,655,880	8,277,120
	....	8	542,400	2,169,600	4,881,600	8,678,400
	....	9	569,640	2,278,560	5,126,760	9,114,240
	....	10	595,560	2,382,240	5,360,040	9,528,960
	....	11	621,960	2,487,840	5,597,640	9,951,360
	....	12	642,600	2,570,400	5,783,400	10,281,600
	....	13	664,680	2,658,720	5,982,120	10,634,880
	....	14	683,880	2,735,520	6,154,920	10,942,080
	....	15	703,080	2,812,320	6,327,720	11,249,280
	....	16	721,080	2,884,320	6,489,720	11,537,280
	....	17	738,120	2,952,480	6,643,080	11.809.920
	....	18	753.960	3,015,840	6,785,640	12,063,360
	....	20	785,520	3,142,080	7,069,680	12,568,320
	....	22	803,280	3,213,120	7,229,520	12,852,480
	....	25	854,880	3,419,520	7,693,920	13,678,080
	....	30	910,680	3,642,720	8,196,120	14,570,880
	....	35	960,960	3,843,840	8,648,640	15,375,360
	....	40	1,006.680	4,026,720	9,060,120	16,106.880
	....	45	1,046,520	4,186,080	9,418,680	16,744,320
	....	50	1,081,920	4,327,680	9,737,280	17 310,720
	....	60	1,137,120	4.548,480	10,234,080	18,193,920
	....	75	1,223,400	4,893,600	11,010,600	19,574,400
	....	90	1,304,400	5,217,600	11,739,600	20,870,400
	....	100	1,336,920	5,347,680	12,032,280	21,390,720

Multipliers for pipe diameters other than given in Table 3.

[Apply the multiplier to the figures given in Table 3 for 1-inch tubing.]

Diameter of pipe.	Multiplier.	Diameter of pipe.	Multiplier.	Diameter of pipe.	Multiplier.
Inches.		*Inches.*		*Inches.*	
1½	2.25	5⅝	31.64	8¼	68
2½	6.25	6	36	9	81
4¼	18	6¼	39	10	100
4⅝	21.39	6⅝	43.9	12	144
5	25	8	64		

PITOT TUBE WITH ATTACHMENT FOR MEASURING STATIC PRESSURES.

For the most accurate measurements by means of the Pitot tube a device is attached for recording static pressures (fig. 5). According to Rowse[a] the piezometer or its equivalent is the most reliable means of obtaining the static pressure. This device embraces a pipe with a few very small circular holes in it, so combined with a larger pipe as to leave an annular space between them (fig. 5). This annular space is closed at the outer end, the other being connected to one end of the gage glass by means of a rubber tube. The other end of the gage glass is so connected to the Pitot tube as to give the dynamic pressure. The difference between the two pressures (the velocity head) is read on the gage glass.

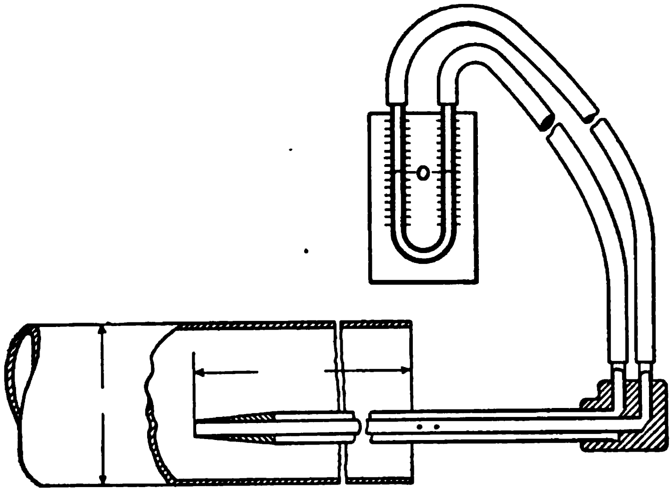

FIGURE 5.—Pitot tube with attachment for measuring static pressures.

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[a] Rowse, W. C., Pitot tubes for gas measurement: Jour. Am. Soc. Mech. Eng., vol. 39, September, 1913, p. 1341.

FORMULA FOR ACCURATE DETERMINATIONS.

The following data are given here in order to show the derivation of a formula for use in more accurately determining the flow of gas through a pipe than by means of the table given on page 38.

According to the well-known formula,

$$h=\frac{144WH}{X}$$

where

h=velocity head in feet of gas.
W=weight of water in pounds per cubic inch.
H=velocity head in inches of water.
X=weight of a cubic foot of gas.

Then when h is known the velocity of gas (in feet per second) is given by the formula,

$$V=\sqrt{2gh}$$

Multiplying through by A,

$$AV=A\sqrt{2gh} \qquad (1)$$

Then

$$Q=60A\times 8.019\sqrt{h} \qquad (2)$$

where

h=velocity head in feet of gas.
g=acceleration of gravity=32.16 feet per second.
A=cross-sectional area, in square feet, of the pipe from which the gas is flowing.
Q=quantity of gas in cubic feet per minute.

Substituting in *2* the value of h we have:

$$Q=60A\times 8.019\times\sqrt{\frac{144\ WH}{X}}$$

$$=60A\times 8.019\times 12\sqrt{\frac{WH}{X}}$$

As

X=specific gravity of gas times the weight of 1 cubic foot of air,

therefore

$$Q=60\times A\times 8.019\times 12\sqrt{\frac{WH}{\text{weight of 1 cubic foot of air}\times\text{specific gravity of gas}}}$$

$$=(5773.68)A\sqrt{\frac{WH}{\text{weight of 1 cubic foot of air}\times\text{specific gravity of gas.}}}$$

The latter equation is rather similar to that used by Rowse.[a] It requires the determination of the following values: The specific gravity of the gas at a certain temperature and pressure; the weight of a cubic foot of air under the same conditions; the weight of water in pounds per cubic foot at the same temperature; the determination of the differences in inches of the water levels in the gage glass, and the cross-sectional area, in square feet, of the pipe from which the gas is flowing.

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[a] Rowse, W. C., op. cit., p. 1372.

In figure 6 are shown the weights of 1 cubic foot of air at various temperatures, with a constant pressure of 30 inches of mercury.[a]

In figure 7 are shown the weights of water, in pounds per cubic inch, at different temperatures.[b]

Below are tabulated the cross-sectional areas of pipes of various diameters:

Cross-sectional areas of pipes of different diameters.

Diameter in inches.	Square feet.	Diameter in inches.	Square feet.
1	0.006	3½	0.0668
1½	.0123	4	.0872
2	.0211	4½	.1104
2½	.0341	5	.1363
3	.0491	6	.1963

EXAMPLES SHOWING ACCURACY OF FORMULA.

The authors have worked out the following examples in order to show the variation in the results from using the more accurate formula given on page 41, as compared with the results obtained by using the table given on page 39.

EXAMPLE 1.

Suppose the atmospheric pressure to be 14.65 pounds per square inch, the temperature 60° F., the water-gage reading 2 inches, the diameter of the pipe 6 inches, and the specific gravity of the gas 0.60.

From the formula

$$Q=(5773.68)A\sqrt{\frac{WH}{\text{weight of 1 cubic foot of air}\times\text{specific gravity of gas.}}}$$

From figure 7 the weight of water (W) in pounds per cubic inch at 60° F. is found, and from figure 6 the weight of 1 cubic foot of air at 60° F. and 14.65 pounds per square inch is determined.

From the table above the area (A) in cubic feet for a 6-inch pipe is found. H, the inches of water, is read from the gage.

Substitution of these values gives:

$$Q=5773.68\times0.1963\sqrt{\frac{0.03608\times2}{0.0761\times0.6}}$$

$$=1428.17 \text{ cubic feet per minute.}$$

or 2,056,564 cubic feet of gas in 24 hours.

Using the same data but referring them to the approximate values given in the table on page 39, one finds the quantity of gas to be 2,103,185 cubic feet in 24 hours. The difference is 46,621 cubic feet, or 2.3 per cent of the first value.

EXAMPLE 2.

Suppose a water-gage reading of 0.3 inch on a 6-inch pipe at 60° F. and 14.65 pounds per square inch, the specific gravity of the gas being 0.6. Proceeding as in the first example, according to the formula:

$$Q=(5773.68)\times1963\sqrt{\frac{(.03608)\times0.3}{(.0766)\times0.60}}$$

$$Q=555.4 \text{ cubic feet of gas per minute.}$$

$$=799{,}800 \text{ cubic feet per 24 hours.}$$

By referring the given data to the table on page 39 one obtains a result of 740,448 cubic feet. The difference is 59,352 cubic feet, or 7.4 per cent of the first value.

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[a] Rowse, W. C., op. cit., p. 1379.

[b] Rowse, W. C., op. cit., p. 1380.

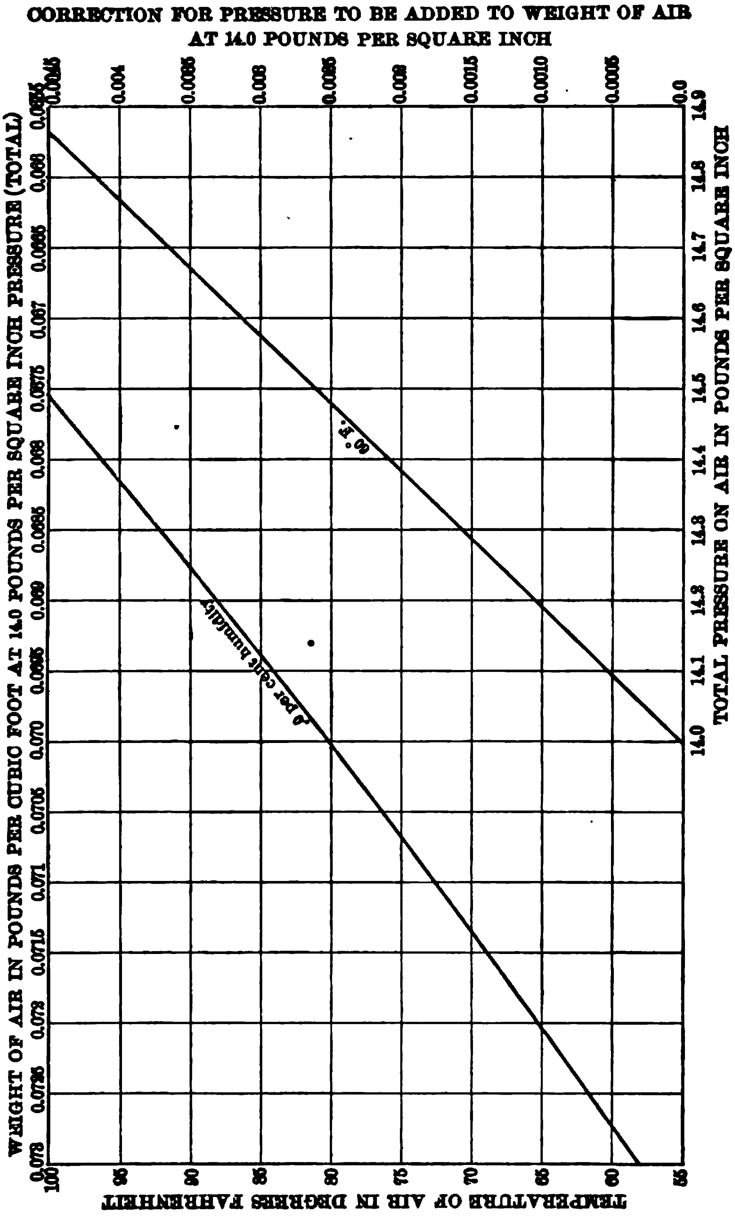

FIGURE 6.—Weights of 1 cubic foot of air at various temperatures, pressure being constant at 30 inches of mercury.

EXAMPLE 3.

Suppose a water-gage reading of 0.3 inch on a 1-inch pipe at 60° F. and 14.65 pounds per square inch, the specific gravity of the gas being 0.60.

From the table on page 39 the cubic feet of gas per 24 hours is found to be 20,568. If the more exact formula be used, the quantity of natural gas per 24 hours is found to be 21,824. The difference is 1,256, or 5.8 per cent.

These three examples will serve to show the errors involved in gas measurement by means of the Pitot tube when the static pressure of the gas is not measured. As regards the measurement of a gas flow on a lease for the purpose of determining the quantity available for gasoline making, the use of the more simple form of Pitot tube appears to be satisfactory.

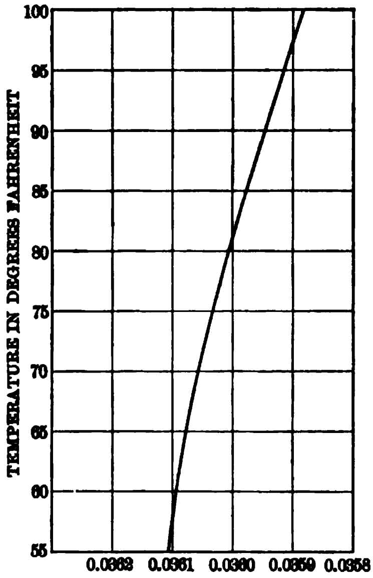

FIGURE 7.—Weights of water at different temperatures, pounds per cubic inch.

GENERAL COMMENTS ON USE OF PITOT TUBE.

The Pitot tube proves most satisfactory when an especially designed instrument is permanently installed. It can then be made an instrument of considerable precision. The use of the accurate form described by the authors is not advisable for field work, unless a device is attached whereby the tube can be rigidly held in place when the readings are made.

Rowse[a] sums up his experiments by saying that the results obtained in measuring gases by an absolutely correct Pitot tube may vary 1 per cent, more or less, from the correct results when the static pressure is correctly obtained and when all readings are taken with a reasonable degree of refinement.

NECESSITY OF ALLOWING A WELL TO VENT FREELY BEFORE PITOT-TUBE READINGS ARE MADE.

The authors know of a gasoline plant that failed because the gas flow from a well was not accurately measured before the plant equipment had been installed. Many wells on the lease had been open for some time and did not produce enough gas to warrant the installation of a plant. One well that had been closed, on measurement with the Pitot tube, registered a flow of gas of 200,000 cubic feet per 24 hours. A plant was installed against the advice of the company that sold the machinery and without its knowledge of the true condition of affairs. After the first day's operation of the plant there was not enough gas left to run the gas engine, and finally the flow practically stopped. The plant, which had cost $7,000, was a failure. This example illustrates the necessity of allowing wells to vent their gases freely before measurements are made, so that the operator may be assured that the quantity measured represents the quantity that will be available for operation of a gasoline plant. Some wells should be open for at least 24 hours before their flow is measured.

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[a] Rowse, W. C., op. cit., p. 1341.

In the rush to install gasoline plants in the early days of the industry operators made great blunders. The authors know of one plant that was installed to work upon gas that had not been tested as to quality. The gas proved to be "dry" and the plant was a failure. The authors have heard of other similar mistakes.

INTERPRETATION OF RESULTS OF TESTS.

Considerable experimenting with plant operation on a large scale was necessary before results could be obtained from laboratory tests that could be used as a guide in making plant installations. The Bureau of Mines and different testing laboratories have at present records of the absorption results, specific gravities, and analyses of different natural gases from which gasoline is commercially produced. Reference is made to those results in the examination of new samples.

Many experiments have shown that gasoline may be obtained from natural gas having a specific gravity of 0.80 and higher (air = 1). Some inconsistencies have been noted, however, so that the authors would hesitate to recommend the installation of a plant to handle a gas that tests showed to have a specific gravity as low as 0.80 or to have an absorption percentage of 30.0 (Bureau of Mines test), although the gas might be all right for the purpose, especially if it were from wells in a field where other gases of low specific gravity were already producing gasoline. The authors do believe, however, that a gas with a tested specific gravity as high as 0.95 and an absorption percentage as high as 40 might warrant an installation.

Natural gases differ much in composition. A so-called "wet" gas might, for instance, contain a very large proportion of methane, with little ethane, propane, or butane, but enough of the gasoline hydrocarbons to warrant a plant installation. Such a gas when subjected to comparatively low pressures would deposit the gasoline vapors. Another gas of the same specific gravity might contain a comparatively small proportion of methane and ethane and a large proportion of propane and butane, but not enough of the gasoline hydrocarbons to warrant plant installation. Therein lies the reason why specific-gravity, solubility, or combustion tests can not always be relied on.

As regards a natural gas of low specific gravity and low absorption percentage (known as a "lean" gas), the safest recourse is to test by means of a portable outfit consisting of a gas meter, small gas engine, compressor, cooling coils, and receiver. Such an outfit can be hauled from place to place on a wagon. This method is in all cases to be recommended as having distinct advantages over laboratory tests. However, it is true that tests made with the portable outfit may be misleading unless in charge of a careful and experienced person.

The authors have also used a small stationary outfit consisting of a meter with a capacity of 15,000 cubic feet per 24 hours, a small compressor, driven by a steam engine, 100-foot cooling coils made of 1-inch pipe, immersed in a tank of water, and a storage tank 5 feet high made of a 6-inch piece of pipe. To the latter was attached a relief valve which could be set to operate at the desired pressure. A trap was installed between the compressor and the cooling coils to catch oil that was sometimes brought from the wells with the gas. A glass gage was connected to the storage tank to indicate the volume of condensate produced.

In conducting tests of a gasoline plant the plant is first operated for an hour or two to insure that everything is working well. The meter and all pressure gages must be in good order. The cooling coils should dip enough to drain readily the gasoline into the storage tank. The efficiency of the cooling coils can be ascertained fairly well by measuring the temperature at different places in the water of the tank. At the point where the coil enters the water it will be hot enough to warm the water appreciably, but if the tank is large and a sufficient length of pipe for cooling purposes is installed this warming of water is only local.

There follows a form used by the authors in testing wells on a given lease. The data shown represent an actual "plant" test:

Date, *March 7, 1913.*
Number of wells, *4.*
Temperature of gas at meter, *58° F. (14° C.).*
Pressure of gas at meter, *Atmospheric.*
Pressure in accumulator tank, *300 pounds per square inch.*
Temperature of water in cooler, *54° F. (12° C.)*
Gas used, *1,100 cubic feet.*
Condensate produced, *0.83 gallon per 1,000 cubic feet.*
Gravity of gasoline produced, *85° B.*
Evaporation loss of condensate on exposure to air, *11 per cent in 3 hours.*
Gravity of gasoline after evaporation loss, *82° B.*

Table 4 following shows the quantity of gas issuing from 16 wells on the same lease. The gas all comes from the same sand, the Berea grit, in West Virginia. The wells had been drilled about 10 years and the oil production averages about 25 or 30 barrels a day from 52 wells. The gas from all of the wells was not tested by the authors.

TABLE 4.—*Results of laboratory and field tests of 16 different wells on the same lease.*

Number of well.	Flow.	Specific gravity of gas (air=1).	Claroline and alcohol absorption.	Number of well.	Flow.	Specific gravity of gas (air=1).	Claroline and alcohol absorption.
	Cubic feet per 24 hours.				*Cubic feet per 24 hours.*		
1	25,000	0.79	33	10	17,000 to 29,000	0.75	24
2	21,500	.67	23	11	76,000	.73	27
3	26,000	.74	28	12	80,000	.73	27
4	12,000	.74	28	13	27,000	.76	27
5	55,500	.71	34	14	36,000	.83	42
6	41,000	.78	32	15	23,000	.84	39
7	46,000	.70	23	16	13,100	.72	30
8	84,000	.71	21				
9	9,000	.78	31				

A gasoline plant capable of taking care of 100,000 cubic feet of gas daily was in operation on this lease and was connected to wells 1, 6, 14, and 15, mentioned in the above table. Some gasoline was produced, but the successful operation of the plant had not been assured when the authors visited the lease. About 1,200,000 cubic feet of gas was available. Certain wells, among them many of high capacity, notably Nos. 2, 3, 4, 5, 7, 8, 10, 11, 12, and 16, appeared to be too dry for consideration for use in the condensation of gasoline from the gas.

RESULTS OF ANALYSES OF NATURAL GASES OF OKLAHOMA.

Following are the results of a laboratory analysis of a natural gas that is used for the condensation of gasoline from natural gas at a plant in the Glenn pool district; 250,000 cubic feet of gas was being used from eight wells. The operators claimed that they obtained about 1¼ gallons of gasoline from each 1,000 cubic feet of gas treated in the plant.

Results of analysis of casing-head gas from Oklahoma.

[Laboratory No. 3868.]

CO_2	0.60
O_2	[a].20
CH_4	60.10
C_2H_6	35.70
N_2	3.40
	100.00

The oil absorption was 20.0 per cent and the specific gravity (air = 1) was 0.75.

The analytical results are interesting as showing a gas from which gasoline is condensed, although it is low in specific gravity and oil absorption as compared with similar values of other samples tabulated below.

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[a] The oxygen is undoubtedly due to a slight leakage of air in the sample container.

The following table shows the specific gravity and the oil absorption of gases obtained from the casing heads of different wells on the same lease in the Glenn pool district of Oklahoma. A gasoline plant had not been installed at the time the authors collected the samples, but one was contemplated. The results show the variation in gases from the same lease and are in marked contrast to the values for the gas mentioned above, which was also collected in the Glenn pool district but from a different lease.

Specific-gravity and oil-absorption values of Glenn pool gas samples.

Laboratory No.	Specific gravity.	Oil absorption.	Laboratory No.	Specific gravity.	Oil absorption.
		Per cent.			*Per cent.*
3787	1.15	55.0	3790	1.11	56.0
3788		72.0	3785	1.31	67.0
3784	1.13	37.0	3786	1.43	78.0

COMPRESSION AND LIQUEFACTION OF THE CONSTITUENTS OF NATURAL GAS IN PLANT OPERATION.

The condensation of gasoline from natural gas is essentially a physical process. If any chemical reactions take place, they are slight and inappreciable. The authors tested residual gases from 10 different plant operations to determine whether carbon monoxide or olefin hydrocarbons were produced. These gases with others are found when the higher paraffins are decomposed at high temperatures and pressures in the absence of air. Neither carbon monoxide nor olefin hydrocarbons were found.

THREE COMMERCIAL PROCESSES.

At present three processes for the extraction of gasoline from natural gas are used commercially. The one most generally used involves compressing the gas to a certain pressure and subsequently cooling it by means of water or air. A second consists in simply cooling the gas without compression by means of a refrigerant, such as liquid ammonia, evaporating under reduced pressure. A third is a combination of the other two.

RELATION OF PRESSURES EXERTED BY GAS MIXTURES.

In order to understand changes that take place in the gas mixture as it passes through the compressors, knowledge of pressures exerted by gas mixtures is essential. In a mixture of gases exerting a certain total pressure each individual constituent of the mixture exerts a part of the pressure. Atmospheric pressure at sea level is about 15 pounds per square inch, of which about 3 pounds is due to the oxygen and about 12 pounds to the nitrogen. In order to be liquefied, a gas must be compressed or cooled or both. If it is to be liquefied by pressure alone, the pressure applied must be greater than the vapor pressure of the liquefied gas when boiling.

When a vapor is mixed with other gases or vapors, only a part of the total pressure is exerted on the vapor. If the vapor constitutes 10 per cent of the mixture, the pressure on the vapor is 10 per cent of the total pressure. For such a mixture, it being assumed that the vapor under consideration will be the first to condense out, a pressure of 150 pounds would be required to have a pressure of 15 pounds on the vapor. Under a pressure of 15 pounds the vapor would begin to condense to a liquid at the temperature at which the liquid would normally boil. Butane boils at 1° C. (34° F.), when its vapor exerts a pressure of 15 pounds per square inch. Hence, to condense butane vapor to liquid at 1° C. (34° F.), there would be required a pressure of at least 15 pounds on the vapor. If the butane constituted 20 per cent of a mixture, there would be needed a total pressure of 75 pounds in order to have a 15-pound pressure on the butane vapor, and to cause condensation to begin. As condensation took place, butane vapor would, of course, be removed from the mixture; that is, its partial pressure would diminish and a pressure greater than 75 pounds would have to be applied to cause the condensation to proceed. Hence, if one knew the exact quantity of butane vapor in a particular natural gas, a pressure greater than that theoretically required to start the condensation would have to be applied in practice. From the above discussion it will be seen why one gas may produce condensate under a pressure of 75 to 100 pounds, whereas another gas may need a pressure of 200 to 300 pounds to produce the same quantity of condensate of the same constituent.

A similar calculation can be made for pentane or other vapors of the liquid paraffin hydrocarbons. The vapor pressures of three of these liquids and of two of the gaseous paraffin hydrocarbons when liquefied are tabulated here.

Vapor pressures of three liquid hydrocarbons at different temperatures.[a]

Temperature.	Vapor pressure of—		
	Pentane.	Hexane.	Heptane.
° C.	*Pounds per square inch.*	*Pounds per square inch.*	*Pounds per square inch.*
0	3.5	0.9	0.2
10	5.4	1.5	.4
20	8.1	2.4	.7
30	11.8	3.1	1.1

[a] Landolt and Börnstein, Physikalisch-chemische Tabellen, 1905, 3d ed., p. 137.

Vapor pressures of two gaseous paraffin hydrocarbons at different temperatures.

Temperature.	Vapor pressure of—	
	Ethane.	Propane.
° *C.*	*Pounds per square inch.*	*Pounds per square inch.*
0	342.5	
12.5		104.4
15.0	474.8	
22.0		132.3
34.5 [a]	735.0	
53.0		249.9
102.0 [a]		713.0

[a] Critical temperature.

If one were to make the assumption that the vapor of pentane only was present in a natural-gas mixture it would be possible to ascertain the pressure necessary to condense this vapor at any desired temperature.

For example, suppose that gas available for gasoline production contains 3 per cent of pentane vapor, and suppose that determination of the pressure necessary to condense this vapor at 20° C. (68° F.) is desired. The above table shows that pentane has a vapor pressure of 8.1 pounds per square inch at 20° C. (68° F.); therefore the pressure required to start the condensation is $\frac{8.1}{0.03}$, or 270 pounds per square inch. As shown on page 25, 1 gallon of pentane will produce when volatilized about 31 cubic feet of vapor at 0° F. (32° C.) and 30 inches of mercury. If a gas yields 1 gallon of pentane per 1,000 cubic feet of gas, then there must be $\frac{31}{1000}$ part, or about 3 per cent of vapor in the mixture. Consequently, when less than 3 per cent of vapor occurs the pressure would have to be raised above 270 pounds to condense the vapor. If a pressure above 270 pounds per square inch and subsequent cooling below 20° C. were not employed, the vapor would not condense.

It has been stated that methane and ethane are never liquefied in plant operation. But propane and butane may be liquefied under certain conditions. At 22° C. (72° F.), to liquefy the vapors of pure propane, a pressure of 132.3 pounds per square inch is required. If 50 per cent of the vapor is present, a pressure of twice 132.3, or 264.6, pounds per square inch is required at a temperature of 22° C. (72° F.). As far as the authors are aware, no vapor-pressure curves for butane have been determined.

But as the boiling point of propane (—45° C.; —49° F.) is much lower than that of butane, the latter will be liquefied more easily than propane. As no data are available, no figures can be given. That butane is a constituent of some natural-gas condensates is shown by the fact that nearly all condensates obtained under high pressure (200 to 300 pounds per square inch) boil at temperatures near 0° C. Of course, the boiling point is modified by the presence of other constituents. Pentane, the next highest homologue to butane, boils at 36.4° C. (97.5° F.).

GASOLINE-PLANT METHODS AND EQUIPMENT.

USE OF COMPRESSORS.

Single and two stage compressors are generally used in gasoline-plant operations. Single-stage compressors are generally used where pressures of 110 pounds per square inch are not exceeded, although they are used at some plants where pressures up to 150 pounds per square inch are employed. At higher pressures, higher temperatures are produced. One of the makers of compressors states that with a 100-pound compressor volumetric efficiencies of 65 per cent are obtained, and with 50-pound compressors efficiencies of 80 to 85 per cent. A 150-pound compressor gives only about 50 per cent efficiency.

LOW-STAGE COMPRESSION.

In the initial stage the gas is subjected to pressures varying from 20 to 50 pounds per square inch. Probably 35 pounds per square inch is an average value. The temperature of the gas may rise to 450° F. (232° C.) in the low-compressor cylinder, but no liquefaction of gas or condensation of vapor will occur. As stated elsewhere, gases can not be liquefied by the application of pressure alone at temperatures above their critical temperature, and at higher temperatures they would have a greater capacity than ever for the vapors present, so that no condensation of the vapors would occur.

COOLING OF MIXTURE.

During the next stage of operation, the mixture passes through a water-cooled 2-inch iron pipe, probably 100 feet long for every 100 cubic feet of gas passed per minute.[a] The cooling is effected at the same pressure as maintained in the low-stage compressor.

Usually little liquid is obtained at this stage of the operation, but that obtained is sometimes collected in the main receiving tank of the plant or in separators provided for the purpose. At a few plants, however, the condensate collected is considerable, being as much as 10 per cent or more of the total, but this yield is exceptional. The quantity of condensate obtained must, of course, principally depend upon the extent of the saturation of the original gas mixture with gasoline vapors. The quantity of gasoline vapors in the gas mixture depends upon many conditions, such as the quantity of gasoline peculiar to the oil, temperature and pressure conditions in the well, intimateness of contact between the oil and gas in the well, composition of the gas, and the treatment the gas receives in the plant.

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[a] One firm that installs gasoline plants allows 1 square foot of radiating surface for each cubic foot of natural gas passing through the coils, an allowance stated to be largely in excess of the needs. The cooling coils are frequently equipped with a by-pass, so that only part of the coil need be used in cold weather.

HIGH-STAGE COMPRESSION.

After the mixture of gas and vapor has left the first cooler it is conducted to the high-pressure cylinder of the compressor and subjected to a pressure varying, perhaps, from 250 to 350 pounds per square inch. The temperature is raised probably to 250° C. (482° F.) in the compression cylinder. Under these conditions no liquefaction or condensation occurs for reasons already mentioned in connection with the discussion of the low-stage compressor. The mixture, still under pressure, is next forced through 2-inch pipe coils, on which water of ordinary temperature falls. In some plants the coils are immersed in tanks of water. An average temperature of probably 32° C. (90° F.) in summer and 4° C. (°39 F.) in winter is maintained. The temperature is further reduced by expanding the gas under the pressure mentioned through a valve into a pipe that envelops the final section of pipe through which the compressed gas travels on its way to the accumulator tank. Expansion against a reduced pressure of 30 pounds per square inch occurs at some plants. A temperature of about 4° C. (39° F.) is normal for a plant using this plan.

CLOSED-EXPANSION SYSTEM.

F. P. Peterson, general manager in the state of Oklahoma for the Riverside Western Oil Co., informed the authors that according to his experience the results obtained from direct expansion of the gases usually fall far short of expectation and that efforts in the direction of more efficient cooling by expansion are being made through what is termed a system of closed expansion. This system involves the use of a cylinder with a piston and a means of resistance against which the gas is made to do work in expanding. Water cooling is avoided as in several other different types of installation.

In the standard type of device for cooling and compressing, as above described, methane and ethane are not liquefied, but butane and, in some plants, propane are. A heavy condensation of gasoline vapors usually takes place, the final mixture containing principally butane, pentane, and hexane. Propane and also heptane may be present. There will also be found some of the gases methane and ethane dissolved in the liquid produced.

CHANGES IN GAS ON COMPRESSION AND COOLING.

The gas, in passing through the compression and cooling coils, undergoes several changes; one has to do with the condensation of vapor, another with the liquefaction of gas, and a third with the solution of gases and vapors in the liquid produced. The vapor condensation depends simply upon the reduced capacity of the different gases to carry the vapors when subjected to increased pressure and lowered temperature. The liquefaction of natural gas depends upon the temperatures and pressures at which the gases butane and propane are liquefied at their partial pressures. The solubility depends upon the solubility of the gases in the liquids produced at the particular temperature and pressures encountered. The three changes mentioned are so intimately concerned with each other that one factor can not be disturbed without affecting the others. For instance, such a pressure above and temperature below those at present ordinarily used could be maintained as to increase to some extent condensation of the most desired constituents, pentane, hexane, and heptane, but with increasing pressure and lowered temperature more of the undesirable gaseous constituents would become liquefied. These, when exposed to the atmosphere, immediately volatilize, carrying with them some of the gasoline constituents. At increasing pressures more of the gases methane and ethane dissolve. With release of pressure they would escape with violent agitation and further loss of the condensate.

Present methods of treating the raw gas have resulted from actual plant experiments on a large scale. Little record of these experiments has ever been published. The standard equipment herein mentioned is the result to date. Improvements in the process are bound to take place, but they must follow established laws of condensation, liquefaction, solubility, etc. The authors know of commercial ventures that were failures because of the management's lack of knowledge of the fundamental laws of physics and chemistry and of the nature of the material they were dealing with.

For the purpose of picturing just the physical changes that take place in the process a diagram such as that constituting figure 8 is instructive.

Suppose one starts with a natural gas at atmospheric temperature and pressure, and suppose it contains a certain weight of a vapor of a liquid hydrocarbon, M, which exerts a part of the total pressure of the mixture. This vapor must be dry, saturated, or superheated. Assuming it to be superheated the condition of 1 pound of it may be represented by the point a, figure 8. In the diagram the ordinates represent pressures and the abscissas, volumes. The point a fixes the volume Va and the pressure Pa of a pound of the vapor at the temperature t. Now the pressure is increased until the point b is reached, representing the boiling point of the liquid at a certain temperature and pressure; condensation begins and continues at constant pressure until complete at b_1b. The line abb_1c is the isothermal line at the temperature t.

As the vapor of the liquid hydrocarbon constitutes only a part of the gas mixture, as was first assumed, in order for condensation to begin it is necessary that the gas mixture be compressed to pressures above atmospheric, depending on the partial pressure of the vapor, in order to have a pressure (ordinate of *b*) on the vapor. In practice, however, the problem is complicated. The amount and character of the vapors are only imperfectly known. The most suitable pressures for any given plant operation can be obtained only by actual trial

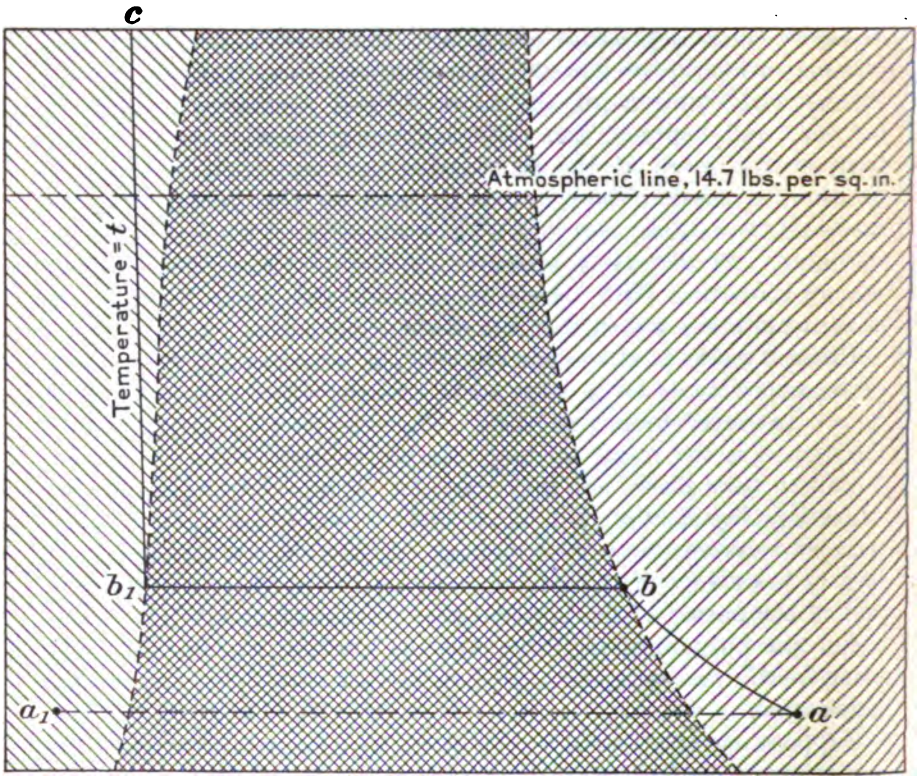


FIGURE 8.—Diagram illustrating physical changes that take place in the production of gasoline from natural gas.

DETAILS OF EQUIPMENT OF GASOLINE PLANTS.

In figures 9 and 10 are shown the plan and elevation of a plant for making gasoline from natural gas by the compression method.

The gas from the wells enters the plant by means of a gas line. After passing through a drip tank *a*, for the removal of oil that might be carried with the gas, it partly circles the compressor building and enters the low-stage compressor; after compression it is conducted to the low-stage cooling coils, and thence to the high-stage compressor *e*. From this compressor it passes to the cooling coils *c*, and is from them expanded into the cooling coils *d*.

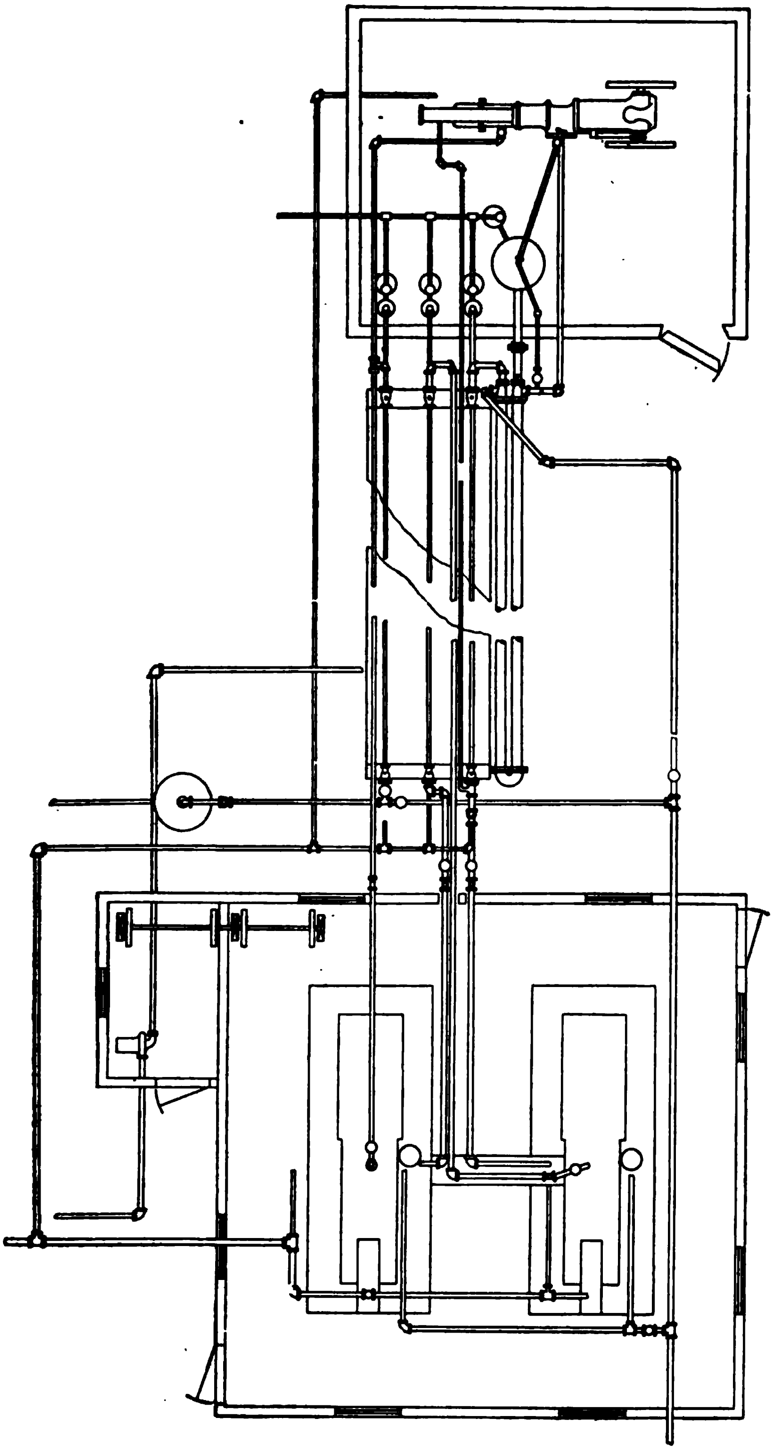


FIGURE 9.—Compression type of plant for making gasoline from natural gas. Plan.

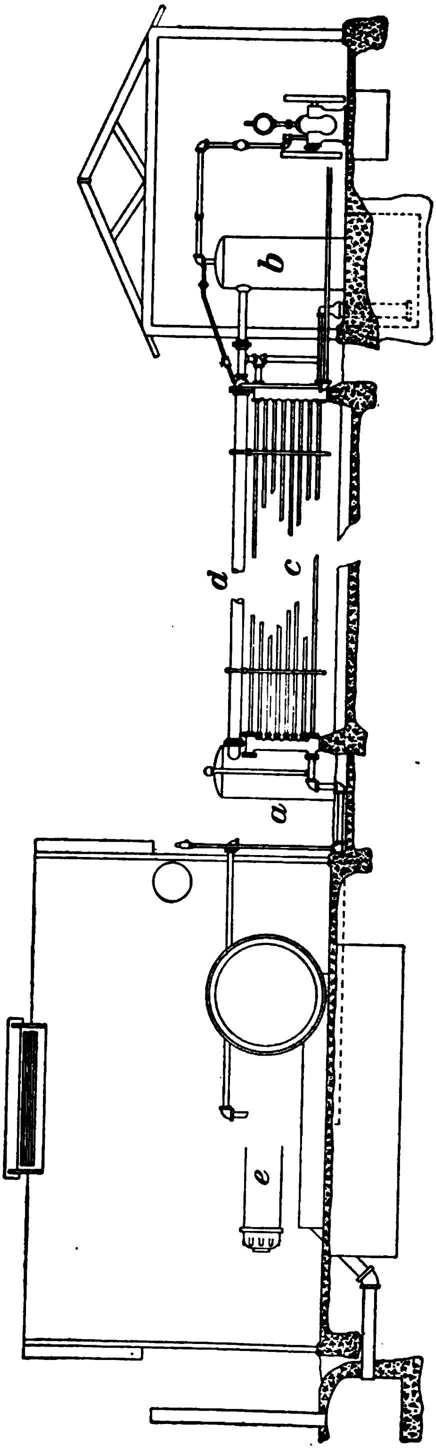


FIGURE 10.—Compression type of plant for making gasoline from natural gas. Elevation.

The condensate is trapped into the accumulator tank *b*, and the residual gas may again be passed back into the compressors through a conducting pipe line. The authors believe that this latter arrangement results in the obtaining of no more condensate, for the residual gas is subjected to the same treatment to which it has already been subjected. In fact the method appears to be wasteful, because the residual gas simply takes the place in the compressors of some gas direct from the wells that could be profitably treated. However the authors have made no experiments to determine this point.

In Plate I, *A*, is shown an exterior view of a gasoline plant at Sistersville, W. Va. The small cooling coils for water cooling and the larger pipes for expansion cooling are shown distinctly.

Plate I, *B*, shows a plant in process of erection in the Glenn pool district, Okla. The expansion coils are jacketed.

Plate I, *C*, shows a small plant at Reno, W. Va. There are many of the smaller plants of this type throughout the Appalachian fields.

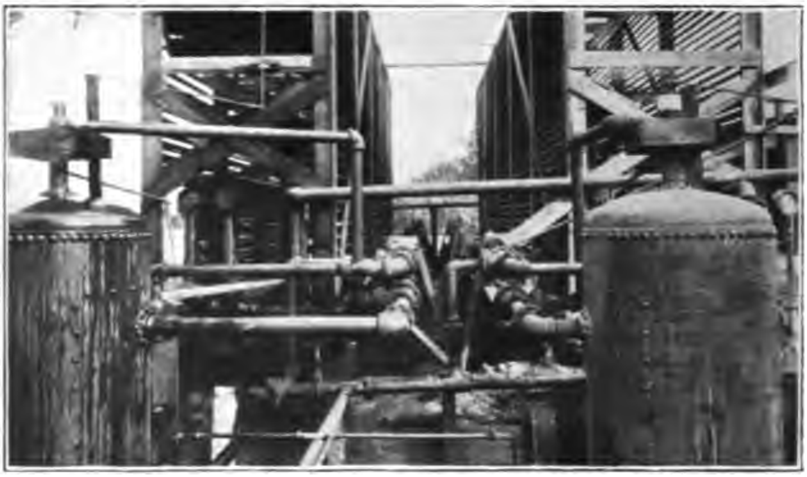
Plate II, *A*, shows the cooling coils and accumulator tanks of another gasoline plant.

Plate II, *B*, shows the interior view of an accumulator-tank house.

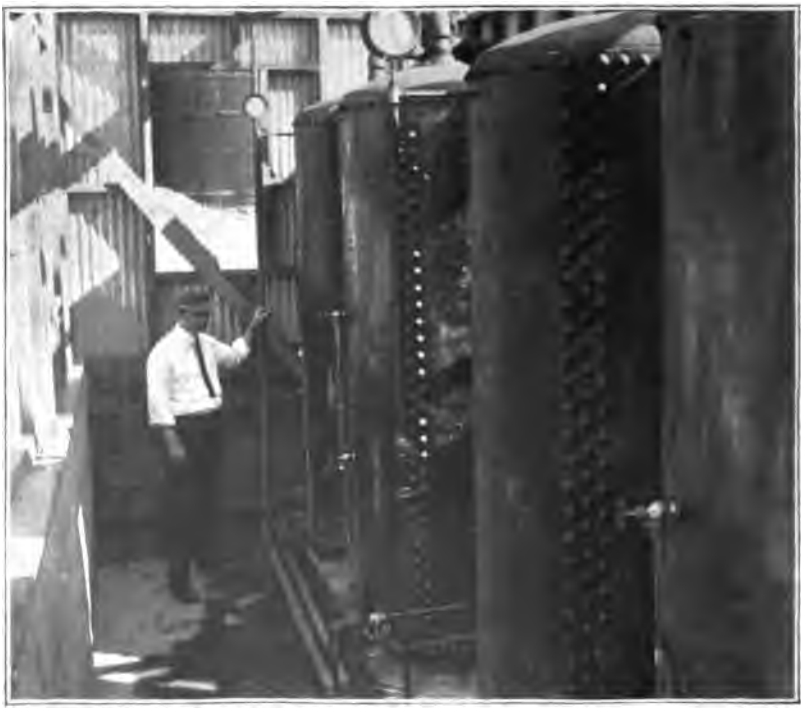
A. EXTERIOR VIEW OF GASOLINE PLANT AT SISTERSVILLE, W. VA.

B. GASOLINE PLANT BEING ERECTED NEAR KIEFER, GLENN POOL, OKLA.

C. SMALL GASOLINE PLANT AT RENO, W. VA.



A. COOLING COILS AND ACCUMULATOR TANKS OF GASOLINE PLANT.



B. GASOLINE-PLANT ACCUMULATOR TANKS.

Plate III, *A*, shows a gas engine and belt-driven compressor of another gasoline plant.

Plate III, *B*, shows an interior view of a plant having both a low-stage and a high-stage belt-driven compressor.

Plate IV, *A*, shows the ruins of a natural-gas gasoline plant that was destroyed by an explosion.

Plate IV, *B*, and Plate IV, *C*, show views of a plant in California that is operated by an ammonia refrigerative system.

Plate V, *A*, shows an oil well from which casing-head gas is drawn for a near-by gasoline plant. The pump shown in the foreground to the left of the picture for pumping the gas from the well is connected to several other wells besides that one shown to the right of the figure. The gas-pipe connection to the oil well is not shown in the view, because it is on the other side of the casing.

Plate V, *B*, shows an exterior view of another gasoline plant in the Glenn pool district. Cooling and storage tanks and oil-well derricks and oil tanks are shown. Ice may be seen on two of the gasoline storage tanks.

Plate VI shows the interior view of the compressor building. Six 50-horsepower direct-driven gas compressors are contained in this room. Such an outfit can handle about 2,500,000 cubic feet of gas per 24 hours.

PLANT TESTS TO DETERMINE EFFECT OF DIFFERENT PRESSURES ON YIELD OF GASOLINE.

Some tests were conducted by the authors to show the grade and quantity of gasoline produced when the crude natural gas was subjected to different pressures during actual plant operation. The natural gas issued from the wells under slight pressure. Meters were being used constantly to measure the gas. The pressure to which the gas is ordinarily subjected is about 140 to 150 pounds per square inch. The following table shows the results of the authors' experiments:

Results of tests of the grade and quantity of gasoline produced when crude natural gas is subjected to different pressures.

Pressure.	Temperature of cooling water.	Gravity of gasoline.	Yield of gasoline per 1,000 cubic feet of gas.
Pounds per square inch.	°*C.*	°*B.*	*Cubic feet.*
110	10	....	1.8
140	10	90	3.0
190	10	94	4.5

It had been found by experiment at this plant that pressures of 140 to 150 pounds per square inch produced the most marketable gasoline. It will be observed that a pressure of 190 pounds produced more gasoline. The extra 1½ gallons, however, was of such a volatile character that it only escaped into the atmosphere upon exposure to the air; hence high pressures at this plant were unnecessary. Gasoline could be obtained by the application of pressures as little as 50 pounds per square inch, but the yield was small.

As natural gas is of different character in many different sections of the country and even in the same oil field, data obtained at one plant can not always be used as a basis for operating other plants—that is, as far as the pressures that should be used are concerned. Each operator should thoroughly test his own gas. Different pressures should be applied and the quantity and character of the gasoline noted. A reliable meter for measuring the gas becomes indispensable. If, in certain plants operating to-day, meters were installed and a series of tests conducted as above outlined much greater efficiency of operation could be attained. Other apparatus that could be used to advantage are thermometers, graduated vessels for measuring the gasoline, hydrometers for determining the specific gravity of the gasoline, and gas-analysis apparatus, especially an apparatus for detecting air leaks in pipes through analyses of the gas for oxygen.

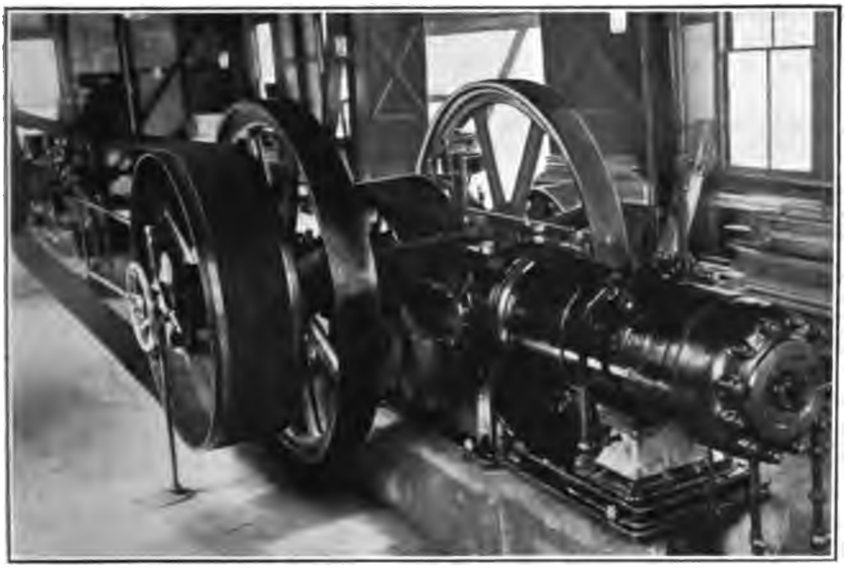
COMMENTS ON METHODS AND EQUIPMENT OF VARIOUS PLANTS.

One plant in McKean County, Pa., obtains only about 72,000 cubic feet per 24 hours from 91 producing oil wells subjected to a reduced pressure of only 1 or 2 inches of mercury. About 4 gallons of gasoline per 1,000 cubic feet of gas is obtained.

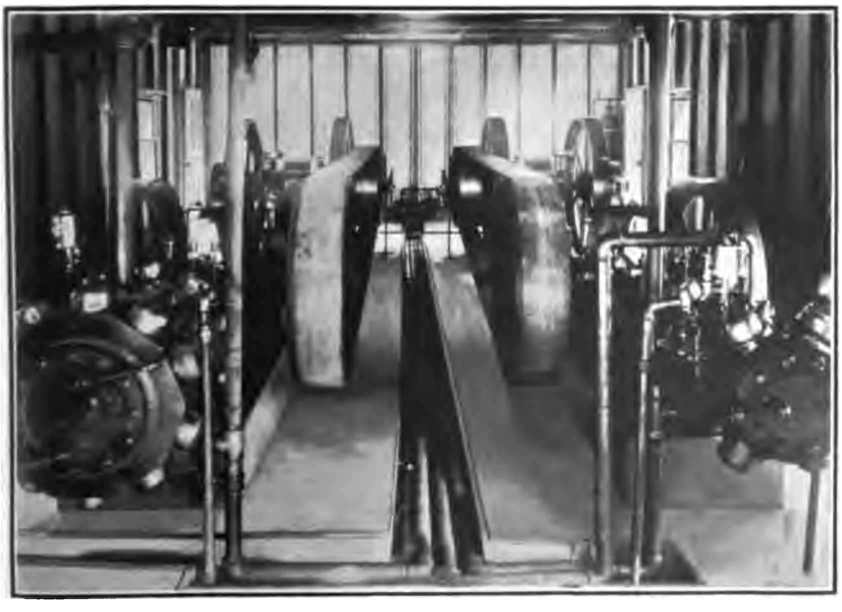
Another plant, about 2 miles distant, obtains about 30,000 cubic feet of gas per hour from 57 wells under a similar reduced pressure.

The only plant in New York situated in the same field as those mentioned above is about 10 miles distant and obtains about 72,000 cubic feet of gas from 60 wells in 24 hours. The wells are drilled in what is known as the third sand. The sand in this locality is spoken of as being "close." At a compression of 250 pounds per square inch and with cooling to about 20° C. (68° F.), the yield of gasoline approximates closely 4 gallons per 1,000 cubic feet of gas. The specific gravity of the condensate is 90° to 95° B.

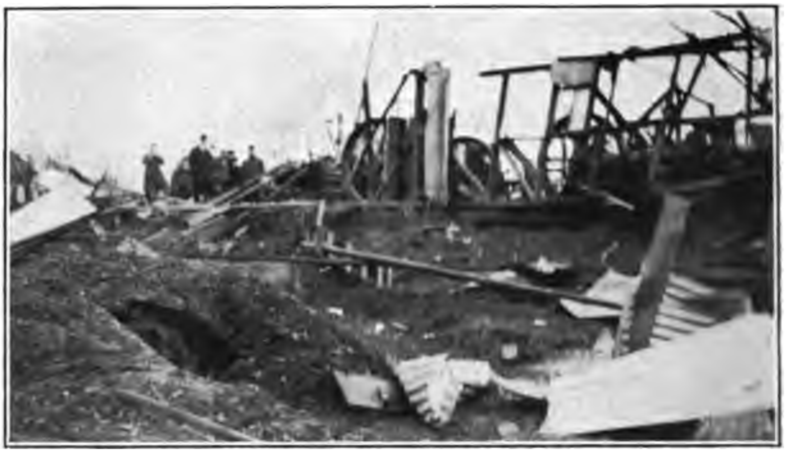
In the region around Tidioute, Warren County, Pa., there is a condition that exists in no other field in the United States as far as the authors are aware. The producing wells tap the third sand, and are subjected to a reduced pressure of about 20 inches of mercury. Any gases and vapors obtained are simply cooled in water and the condensate collected. The amount of vapors obtained per well is rather small and the methods of extraction of gasoline are crude. At only two "plants" is any attempt made to compress the gas, but connected to these are 50 or 60 wells. The majority of the producers in this region pump only a few wells.



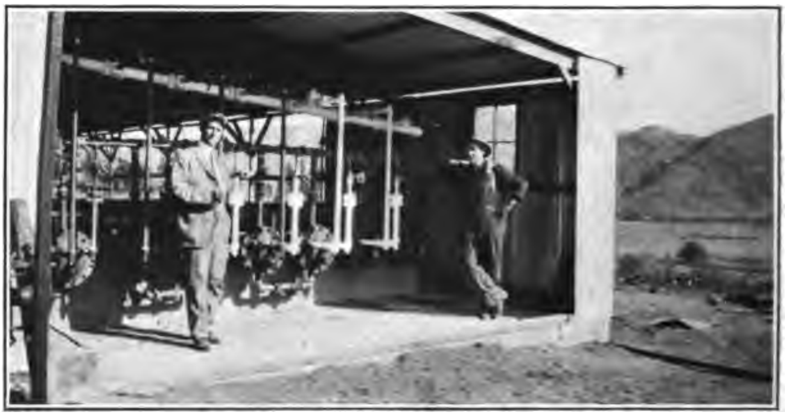
A. GAS ENGINE AND BELT-DRIVEN COMPRESSOR IN GASOLINE PLANT.



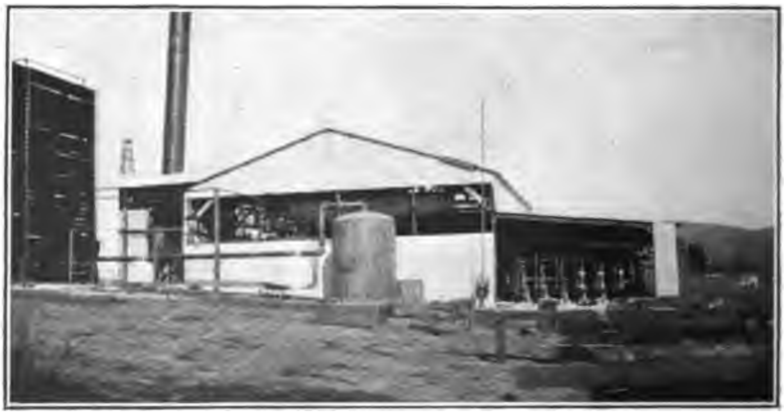
B. DOUBLE-STAGE BELT-DRIVEN COMPRESSOR.



A. RESULTS OF AN EXPLOSION IN A GASOLINE PLANT.



B. PART OF STILL HOUSE OF A PLANT FOR CONDENSING GASOLINE BY REFRIGERATION.



C. GENERAL VIEW OF PLANT FOR CONDENSING GASOLINE BY REFRIGERATION. FROM LEFT TO RIGHT ARE SHOWN THE WATER TOWER, GAS RECEIVER, REFRIGERATING COILS, AND STILLS.

At Hastings, Warren County, Pa., and in the surrounding region the average quantity of gas per well increases over that in the other regions operated in the northern Pennsylvania fields. The quantity of gasoline obtained per 1,000 cubic feet of gas under conditions similar to those in the northern fields is approximately the same.

The oil fields extend south into Butler, Allegheny, and Washington Counties, and many successful plants are in operation in all those counties, although most of them are small. The wells utilized for gasoline production constitute a small proportion of the total number of oil wells, being less than 1 per cent.

As the oil fields extend into West Virginia and Ohio, especially those along the Ohio River on both sides from Steubenville to Marietta, Ohio, more wells are utilized—probably between 25 and 50 per cent of the total number of wells.

In this region are situated some of the largest and best equipped plants in the United States. The gas is as a rule rich in the gasoline-making constituents, approximating on the average close to 3 gallons of 90° to 95° B. gasoline per 1,000 cubic feet of gas treated. Compression at 200 pounds pressure per square inch is employed.

COST OF GASOLINE-PLANT EQUIPMENT.

Compression and condensing equipment that will handle 120,000 cubic feet of gas per 24 hours costs about $2,800. This includes a 15-horsepower gas engine and low-stage compressor for a discharge pressure of 50 pounds per square inch, a 15-horsepower gas engine and high-stage compressor with a discharge pressure of 250 pounds per square inch, intercooler, aftercooler, accumulator tank, expansion coils, and refrigerating coil, and a lighting-plant equipment consisting of a 5-horsepower engine, generator, safety lamps, incandescent lamps, wiring, etc. The gas engines and the compressors are direct connected. The price of equipment varies from $2,800 for equipment for handling the smaller quantities of gas up to $7,800 for equipment capable of handling 600,000 to 700,000 cubic feet of gas. Foundations and housing for machinery, pipe lines to wells, railroad sidings, storage tanks, etc., are extra.

The authors are aware of one small plant from which the owner claims he derives a net income of $150 per month with a small equipment which handles only 60,000 cubic feet of gas in 24 hours. Conditions are such that this man is enabled to attend to this plant in addition to his regular duties. The gas used is exceedingly rich in gasoline vapors.

The authors have knowledge of two plants that cost $40,000 for complete installation, including the cost of compressors, two of them of 50 horsepower, two of 40 horsepower, two of 35 horsepower, and two of 20 horsepower, storage tanks, railroad sidings, and buildings at the sidings, pipe lines to about 120 wells, foundation and housing for equipment, etc. The operating expenses for one year were $11,000. The cost for the salaries of six men included in the operating expenses was $7,000. The other $4,000 was paid for repairing the plant and for waste, oil, etc. The two plants sold 490,000 gallons of gasoline in 1913. For most of the gasoline the company received 13½ cents per gallon. Probably 11¼ cents would be an average price; hence the gross income was 11¼ multiplied by 490,000, or $55,125, the net income therefore being $55,125 less $11,000, or $44,125. The company running these plants, by an unusual agreement, paid to a party from whom they bought the plant a royalty per year of 50 per cent of the profits, hence the owners' net gain was $22,062. Therefore, on the original investment, they realized about 55 per cent return for the year 1913.

PERCENTAGE OF VAPOR CONDENSED BY COMPRESSION AND COOLING.

The change in the raw gas that takes place in the compressors and coolers of a plant consists in the conversion of certain vapors and gases into liquid condition, and the solution of gases in these liquids. To give exact figures for the proportions of gas and vapor that disappear is impossible. An approximation can be reached, however. One gallon of liquid pentane when converted into gas produces about 31 cubic feet of gas at 0° C. and 760 mm. pressure. One gallon of propane in the liquid condition produces about 45 cubic feet of gas. One gallon of butane produces 37 cubic feet of gas. Butane and pentane are probably the two paraffins that are removed in greatest quantity.

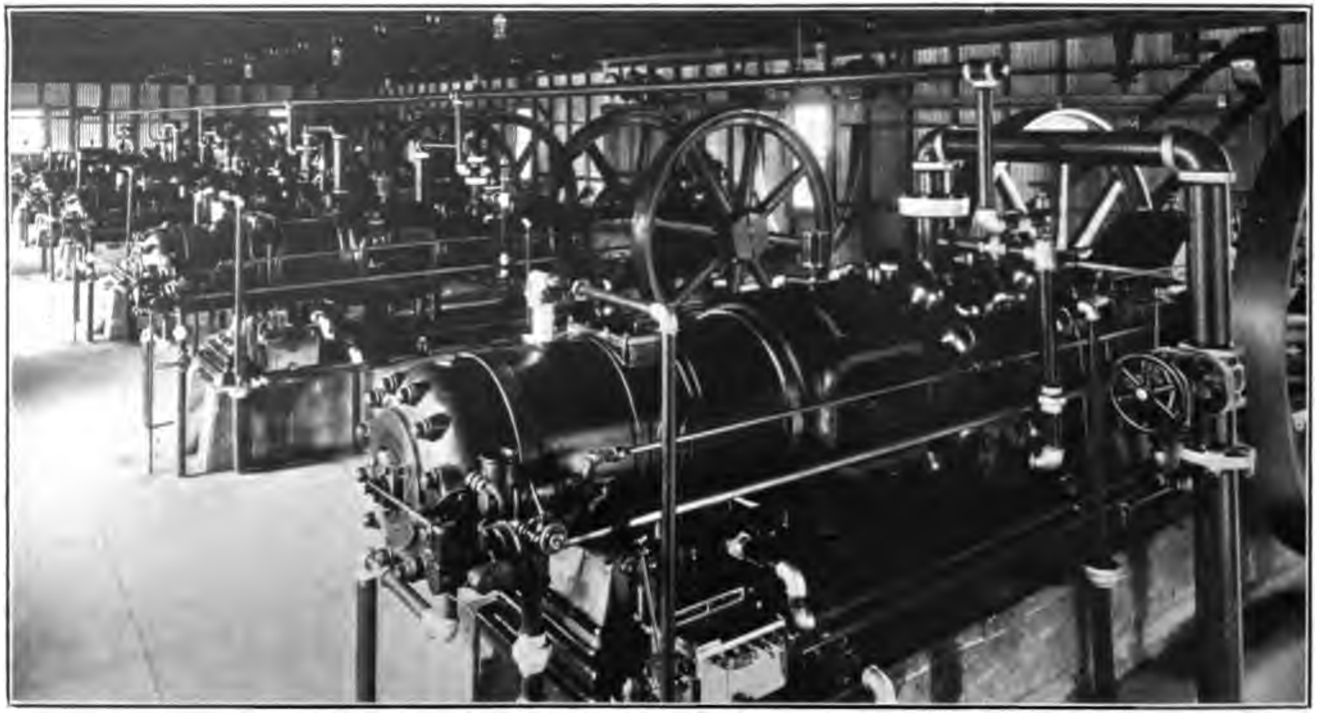
Aside from such liquefaction a certain amount of gas is absorbed by the liquid, as stated above. It is small as regards the total disappearance of gas. The authors estimate that at some plants about 35 cubic feet of gas disappears for each gallon of condensate produced from 1,000 cubic feet of gas. If 4 gallons of condensate per 1,000 cubic feet of gas is obtained, then 140 cubic feet, or about 14 per cent of the gas treated, has disappeared. At some plants, however, as much as 50 per cent of gas disappears, and at others the quantity of residual gas is almost insignificant.

RESULTS OF ANALYSES OF GASES FROM DIFFERENT STAGES OF PLANT OPERATION.

Table 5 following shows the results of laboratory tests of various gases derived from the different stages of plant operation. The percentage of air was calculated from the oxygen content as determined by analysis.

A. OIL WELL FROM WHICH CASING HEAD GAS IS DRAWN FOR NEAR-BY GASOLINE PLANT.

B. EXTERIOR VIEW OF GASOLINE PLANT. COOLING AND STORAGE TANKS, OIL-WELL DERRICKS, AND OIL TANKS ARE SHOWN.



INTERIOR OF A GASOLINE PLANT EQUIPPED WITH SIX 50-HORSEPOWER DIRECT-CONNECTED COMPRESSORS.

TABLE 5.—*Results of laboratory tests of samples of gas from different gasoline plants.*

PLANT 1,[a] NEAR FOLLANSBEE, W. VA.

Condition of gas.	Calculated gross heating value per cubic foot at 0° C. and 760 mm.	Specific gravity at 0° C. and 760 mm. (air=1).	Proportion absorbed by 35 cc. of oil.	Composition.								Remarks.
				Air.	CH_4.	C_2H_6.	C_3H_8.	C_4H_{10}.	N_2.	CO_2.	Total.	
	B. t. u.			*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	
Natural gas as drawn from the well.	2,544	1.46	85.7	......	......	10.8	88.3	......	0.9	......	100	The gas was drawn from 75 producing oil wells, under a reduced pressure of 20 inches of mercury. The gasoline produced was shipped in drums to Pittsburgh, Pa., where it was blended with refinery naphtha for the market.
Residual gas after removal of 50 pounds of compression product.	2,515	1.46	......	......	......	16.9	82.9	......	0.2	......	100	
Residual gas after removal of 250 pounds of compression product.	2,171	1.23	78.2	......	......	59.2	40.3	......	0.5	......	100	
Natural gas as drawn from the well.....	2,474	1.41	83.6	......	......	21.4	78.2	......	.4	......	100	These samples were taken from the same plant as those above, but were taken two months previous.
Residual gas after removal of 50 pounds of compression product.	2,415	1.38	82.0	......	......	26.5	72.4	......	1.1	......	100	
Residual gas after removal of 250 pounds of compression product.	2,022	1.15	63.6	......	......	77.3	22.0	......	.7	......	100	

PLANT 2, NEAR McDONALD, PA.

Condition of gas.	Calculated gross heating value per cubic foot at 0° C. and 760 mm.	Specific gravity at 0° C. and 760 mm. (air=1).	Proportion absorbed by 35 cc. of oil.	Air.	CH_4.	C_2H_6.	C_3H_8.	C_4H_{10}.	N_2.	CO_2.	Total.	Remarks.
Natural gas as drawn from the well......	*B. t. u.* 1,817	1.03	38.5	([b])	2.7	96.1	......	......	1.0	0.2	100	Air was leaking into the pipes in large amount. The output of gasoline was 1¼ gallons per 1,000 cubic feet of crude gas. The gas used was that from producing wells. The gas was obtained under a reduced pressure of 20 inches of mercury. This gasoline was blended with refinery naphtha and then marketed.
	1,273	......	27.0	[c]30.1	1.9	67.3	......	......	.6	.1	100	
Residual gas after removal of 20 pounds of compression product.	1,303	[c].02	[c]30.2	29.0	.7	69.6	......	......	.6	.1	100	
Residual gas after removal of 80 pounds of compression product.	1,220	......	25.0	30.0	7.2	62.0	......	......	.7	.1	100	

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[a] Plant numbers arbitrarily assigned for convenience of reference.

[b] Analysis calculated "air free" to show composition of crude gas. The crude gas was obtained after the gas had been first compressed but not cooled.

[c] Actual composition of the gas delivered to the compressor.

TABLE 5.—*Results of laboratory tests of samples of gas from different gasoline plants*—Continued.

PLANT 3, NEAR McDONALD, PA.

Condition of gas.	Calculated gross heating value per cubic foot at 0° C. and 760 mm.	Specific gravity at 0° C. and 760 mm. (air=1).	Proportion absorbed by 35 cc. of oil.	Composition.								Remarks.
				Air.	CH_4.	C_2H_6.	C_3H_8.	C_4H_{10}.	N_2.	CO_2.	Total.	
Natural gas as drawn from the well......	*B. t. u.* 2,310	1.59	43.0	*P. ct.* (a)	*P. ct.*	*P. ct.*	*P. ct.* 34.3	*P. ct.* 40.6	*P. ct.* 23.0	*P. ct.* 2.1	*P. ct.* 100	The output of gasoline was 3 to 4 gallons of gasoline (90° B.) per 1,000 cubic feet of gas. The gas was drawn from producing wells, under a reduced pressure of 20 inches of mercury. The gasoline was blended with refinery naphtha and then marketed.
	1,650	......	33.0	[b]28.5	......	......	24.5	29.0	16.5	1.5	100	
Residual gas after removal of 20 pounds of compression product.	1,220	......	17.7	[b]29.6	......	25.5	28.1	......	16.0	.8	100	
Residual gas after removal of 80 pounds of compression product.	1,050	......	20.6	[b]30.7	......	43.5	9.0	......	16.0	.8	100	
PLANT 4, NEAR KIEFER, OKLA. (GLENN POOL).												
Natural gas as drawn from the well......	*B. t. u.* 1,344	0.83	......	......	49.1	44.1	......	......	0.7	6.1	100	The output of gasoline was 1½ gallons of "wild" gasoline per 1,000 cubic feet of gas. The gas was drawn from the wells, under a reduced pressure of 20 inches of mercury. The gasoline was blended with refinery naphtha and then marketed.
Residual gas after removal of 250 pounds of compression product.	1,313	.76	22.4	......	60.7	35.8	......	......	.6	2.9	100	
PLANT 5, NEAR FOLLANSBEE, W. VA.												
Natural gas as drawn from well..........	*B. t. u.* 2,417	1.380	64.7	(a)	......	28.5	71.1	......	0.4	100	......	The output of gasoline was 500 gallons in 24 hours from two 35-horsepower compressors.
	2,103	......	57.0	[b]13.0	......	24.8	61.9	......	.3	100	......	
Residual gas after removal of 50 pounds of compression product.	2,015	......	[b]56.6	[b]11.5	......	34.8	53.4	......	.3	100	......	
Residual gas after removal of 225 pounds of compression product.	1,576	......	[b]42.2	[b]18.0	......	74.3	7.3	......	.4	100	......	

[a] Analysis calculated "air free" to show composition of crude gas.

[b] Analysis shows actual composition of gas delivered to compressor.

Table 5.—*Results of laboratory tests of samples of gas from different gasoline plants*—Continued.

PLANT 6, NEAR RIVERSIDE, W. VA.

Condition of gas.	Calculated gross heating value per cubic foot at 0° C. and 760 mm.	Specific gravity at 0° C. and 760 mm. (air=1).	Proportion absorbed by 35 cc. of oil.	Composition.								Remarks.
				Air.	CH_4.	C_2H_6.	C_3H_8.	C_4H_{10}.	N_2.	CO_2.	Total.	
	B.t.u.			*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	
Natural gas as taken from the well	2,369	1.37	48.3	(a)	......	32.2	66.7	......	1.1	100	......	The gas was drawn from the wells under a reduced pressure of 20 inches of mercury.
	1,720	1.27	33.4	b27.4	......	23.4	48.4	......	.8	100	......	
Residual gas after compression to a few ounces	1,657	1.26	31.8	b29.4	......	23.9	45.7	......	1.0	100	......	
	2,348	1.36	45.0	(a)	......	33.9	64.7	......	1.4	100	......	
Residual gas after removal of 70 pounds of compression product.	1,119	.96	23.1	b34.9	10.7	54.0	......	......	.4	100	......	
	1,729	.97	53.6	(a)	16.4	83.0	......	......	.6	100	......	
PLANT 7, NEAR RIVERSIDE, W. VA. (PLANT NO. 9).												
Natural gas as drawn from the well	1,669	......	27.8	b31.1	......	12.4	54.2	......	2.3	100	......	The gas was drawn from 49 wells.
	2,424	1.38	44.1	(a)	......	18.0	78.7	......	3.3	100	......	
Residual gas after removal of 90 pounds of compression product.	1,178	......	23.5	b37.0	......	52.2	7.8	......	3.0	100	......	
	1,872	1.06	37.3	(a)	......	82.9	12.4	......	4.7	100	......	
PLANT 8, NEAR STEUBENVILLE, OHIO.												
Natural gas as drawn from the well	1,810	1.15	51.2	b12.6	......	64.3	23.1	......	......	100	......	
	2,070	1.21	53.7	(a)	......	73.6	26.4	......	......	100	......	
Residual gas after removal of 90 pounds of compression product.	1,615	......	42.5	b15.3	......	79.8	4.9	......	......	100	......	
	1,907	1.08	50.2	(a)	......	94.2	5.8	......	......	100	......	
Residual gas after removal of 160 pounds of compression product.	1,874	1.06	51.3	(a)	......	98.3	1.7	......	......	100	......	
	1,559	......	42.7	b16.8	......	81.8	1.4	......	......	100	......	
PLANT 9, W. VA.												
Natural gas as drawn from the well	2,231	1.29	49.7	(a)	......	47.6	50.7	......	1.7	100	......	Gas was drawn from 35 wells.
	1,444	......	32.8	b5.2	......	30.8	32.8	......	1.2	100	......	
Residual gas after removal of 100 pounds of compression product.	1,931	1.12	39.5	(a)	......	84.3	13.7	......	2.0	100	......	
	1,225	......	25.1	b36.5	......	53.5	8.7	......	1.3	100	......	

[a] Analysis calculated "air free" to show composition of crude gas.

[b] Actual composition of gas delivered to compressor.

TABLE 5.—*Results of laboratory tests of samples of gas from different gasoline plants*—Continued.

PLANT 10, W. VA.

Condition of gas.	Calculated gross heating value per cubic foot at 0° C. and 760 mm.	Specific gravity at 0° C. and 760 mm. (air=1).	Proportion absorbed by 35 cc. of oil.	Composition.								Remarks.
				Air.	CH_4.	C_2H_6.	C_3H_8.	C_4H_{10}.	N_2.	CO_2.	Total.	
	B.t.u.			P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	
Natural gas as drawn from the well......	1,916	1.07	38.4	(a)	......	93.1	6.9	......	......	100	......	Gas was drawn from 100 wells.
	1,521	......	30.7	b20.6	......	73.9	5.5	......	......	100	......	
Residual gas after removal of 125 pounds of compression product..	1,635	......	34.5	(a)	28.4	71.6	......	......	......	100	......	
	1,311	.91	27.7	b19.8	22.8	57.4	......	......	......	100	......	

PLANT 11, NEAR STEUBENVILLE, OHIO.

Condition of gas.	Calculated gross heating value per cubic foot at 0° C. and 760 mm.	Specific gravity at 0° C. and 760 mm. (air=1).	Proportion absorbed by 35 cc. of oil.	Air.	CH_4.	C_2H_6.	C_3H_8.	C_4H_{10}.	N_2.	CO_2.	Total.	Remarks.
	B.t.u.											
Natural gas as drawn from the well......	1,784	1.00	36.9	(a)	9.7	90.3	......	......	......	100	......	Gas was drawn from 26 wells.
	1,616	......	33.1	b 9.4	8.8	81.8	......	......	......	100	......	
Residual gas after removal of 25 pounds of compression product.	1,697	.95	36.3	(a)	20.6	79.4	......	......	......	100	......	
	1,519	......	32.0	b10.5	18.4	71.1	......	......	......	100	......	
Residual gas after removal of 160 pounds of compression product.	1,598	.89	a34.9	(a)	33.0	67.0	......	......	......	100	......	
	1,381	......	b30.2	b13.6	28.5	57.9	......	......	......	100	......	

[a] Analysis calculated "air free" to show composition of crude gas.
[b] Actual composition of gas delivered to compressor.

SIGNIFICANCE OF RESULTS TABULATED.

It is well to again call attention to the fact that the percentages of paraffin hydrocarbons shown in the preceding results of analyses are only approximate. Only the two predominating paraffin hydrocarbons are shown. For instance, in plant 2 the hydrocarbon content of the crude gas is given as CH_4, 2.7 per cent, and C_2H_6, 96.1 per cent. Propane, butane, and vapors of the liquid hydrocarbons must be present, else gasoline could not be condensed from the gas. The total hydrocarbon content is correct or nearly correct, however, as is the specific gravity and heating value. The oil absorption shows only the relative solubilities of the different gases under a certain condition. One can determine approximately the relative changes that take place in the plant operation by comparing the different analytical results. For instance, the figures for plant 6, near Riverside, W. Va., indicate that the gas underwent only a small change after compression in the first stage to a pressure of a few ounces. The specific gravity changed only from 1.27 to 1.26, the heating value dropped inappreciably, the oil absorption was only slightly different, and there was scarcely any change in the chemical analysis. After compression to 70 pounds per square inch, however, the gas changed markedly.

Regarding the results for plant 1, the chemical analysis, the specific gravity determination, and the claroline oil absorption show the gas represented to be a rich one. It will be seen that little difference existed between the composition of the crude gas and the same gas after it had been compressed to a pressure of 50 pounds per square inch. Only after the compression to a pressure of 250 pounds per square inch and cooling, did the composition of the gas mixture change appreciably.

The results obtained with the gas from plant 2, a small plant near McDonald, Pa., show that the crude gas was not very "wet." The absorption by claroline oil was rather low, and the gas was probably near the lower limit of a gas adapted for the production of gasoline. The composition of the gas was not changed to a very marked degree at any stage in the plant operation.

The results obtained with the gas from plant 3, 1 mile from plant 2, and the results with the gas from the latter plant show in a marked degree how natural-gas samples may vary in the same field. After the sample from plant 3 had been compressed to 20 pounds per square inch and cooled, a considerable change in the composition took place. The composition also changed considerably after compression to 80 pounds per square inch and cooling. Nearly 50 per cent of the gas delivered to the compressor consisted of air and nitrogen.

The results for plant 4, in the Glenn pool district, Okla., cover a gas probably about as poor as can be handled commercially. The condensate produced is extremely volatile. Other samples of gas from this same field are rich in gasoline vapors.

The results for plant 5 represent a gas that was derived from wells in the immediate vicinity of those connected with plant 1. The gas is of the same general character. The greatest change occurs after compression to 225 pounds per square inch and cooling.

Regarding plant 6, near Sistersville, W. Va., compression to a few ounces per square inch and cooling produced no gasoline, but after compression to 70 pounds per square inch and cooling, the gas underwent a considerable change in composition. A heavy condensation of gases and vapors occurred.

As regards the results for plant 8, near Steubenville, Ohio, most of the condensate was produced after the gas had been compressed to 90 pounds per square inch and cooled. Increasing the pressure to 160 pounds per square inch and cooling gave little additional yield, as is shown by the test results.

In plant 9 one-stage compression and cooling was practiced. High-grade plant equipment and excellent methods of handling the product were in use.

In plant 10 the composition of the gas, after compression to 125 pounds per square inch and cooling, changed markedly. Compression to any higher pressures would probably be useless, in view of the composition of the waste gas.

GENERAL CONCLUSIONS.

In general the preceding table shows that under existing methods of plant operation condensate is extracted from natural gas that ranges in specific gravity from as low as 0.83 to as high as 1.59 (air = 1) and that the solubilities of the gas in claroline oil ranges from 36.9 (air free) to 85.7 per cent, according to the well from which it comes.

The authors hesitate to recommend the installation of a plant to handle natural gas that shows results as poor as the minimum values given in the table. Such gas might produce gasoline in paying quantities and might not. Probably the safest extremes would be a specific gravity of 0.95 (air = 1), and a claroline-oil absorption of 40 per cent. The natural gas supplied to Pittsburgh, Pa., with which the authors are most familiar, contains little of the gaseous hydrocarbons, has a specific gravity of 0.64 (air = 1), and has a claroline-oil absorption of about 16 per cent. It is a dry gas and is unsuitable for gasoline production.

It will be seen that in many of the plants the gas delivered to the compressor contained 20 to 40 per cent of air due to inleakage either through the rock strata or through defective connections in the gas lines. Such leakage is obviously undesirable and every effort should be directed toward its prevention.

The waste gases from some plants seem to contain considerable quantities of gasoline-making constituents, as may be observed from the analytical results, including the specific-gravity determinations, and the percentages of gas that was absorbed by claroline oil. The waste gases escape directly from the accumulator tank containing the last-stage compression products. These products at the existing temperatures have high vapor pressures, and consequently the escaping gases carry with them some of the vapors of the liquid in the tank.

SPECIFIC GRAVITIES AND ABSORPTION NUMBERS OF NATURAL GASES USED FOR CONDENSATION OF NATURAL GAS.

The authors have compiled the following table to show at a glance the specific gravities and absorption numbers of natural gases used for the condensation of natural gas. The table is compiled from the results shown in the large table preceding. The compilation will be useful for reference in predicting the results that may be obtained from other samples of natural gas.

Specific gravities and absorption numbers of samples of natural gas used for making gasoline.

No.	Specific gravity (air=1).	Absorption number.	No.	Specific gravity (air=1).	Absorption number.
1	1.46	86	7	1.37	48
2	1.41	84	8	1.38	44
3	1.68	39	9	1.21	54
4	1.59	43	10	1.29	50
5	.83	28	11	1.07	38
6	1.38	65	12	1.00	37

FIRE HAZARD AT GASOLINE PLANTS.

Serious accidents have occurred in the manufacture of gasoline from natural gas and in the transportation of the gasoline. Several plants have been completely wrecked through the explosions of gas-air mixtures that have resulted from the escape and ignition of natural gas in the engine and compressor rooms. Storage tanks have also been demolished when they have burst owing to excessive pressures put on them. Safety valves must be in good working order, and great care should be exercised in installing electric wiring systems and magnetos. All electric wiring should be properly placed, well insulated and made secure on supports. Fuses or electric switches should never be placed inside of buildings where gas might escape. Lighting dynamos and magnetos should be installed in small buildings outside the main building. Electric-light bulbs should be protected by wire guards, because they may ignite explosive mixtures if they are accidentally smashed.[a]

The following table shows the small percentages of gases and vapors occurring in natural gas that are required to form explosive mixtures with air:

Low explosive limits for paraffin gases and vapors.[b]

Hydrocarbon.	Proportion of gas-air mixture constituting low explosive limit.	Hydrocarbon.	Proportion of gas-air mixture constituting low explosive limit.
	Per cent.		*Per cent.*
Methane	5.60 to 5.70	N butane	1.60 to 1.70
Ethane	3.00 to 3.20	N pentane	1.35 to 1.40
Propane	2.15 to 2.30		

According to the above table, even if a natural gas consisted almost entirely of methane, as some natural gases do, an explosion would follow an ignition of a mixture of air and natural gas containing 5.50 per cent of methane. The natural gas of Pittsburgh contains an appreciable quantity of ethane and propane. The authors have determined its explosive limits to be about 5 per cent gas, low limit, and about 11.6 per cent gas, high limit. The "wet" gases, or those from which gasoline is condensed, contain a much higher proportion of the higher paraffin hydrocarbons than does the natural gas of Pittsburgh, and consequently have narrower explosive limits. Their low explosive limits are much lower. The authors have made no determination of the explosive limits of the "wet" natural gases from which gasoline is condensed, but they can closely estimate for many "wet" gases that such limits will range from about 3.5 per cent gas, low limit, to about 9.5 per cent gas, high limit. That is, when some "wet" natural gases are present in the mixture of the gas and air, an explosion will occur between these limits, although the limits for different natural gases will vary somewhat from the figures mentioned.

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[a] Clark, H. H., and Ilsley, L. C., Ignition of mine gases by the filaments of incandescent lamps: Bull. 52, Bureau of Mines, 1913, 31 pp.

[b] Burgess, M. J., and Wheeler, R. V., The lower limit of the inflammability of mixtures of the paraffin hydrocarbons with air: Trans. Chem. Soc., vol. 99, 1911, pp. 2013, 2030.

It will be observed then that only a small proportion of the gas need be mixed with air to form an explosive mixture, and that great care should be exercised to guard against leaks of the gas in plant buildings.

EFFECT OF LEAKAGE OF AIR INTO PIPES AND CONNECTIONS.

As mentioned before, at many oil wells that are connected to gasoline plants the gas is drawn at reduced pressures as low as 25 inches of mercury. Manifestly, under such low pressure, pipe and other connections must be very tight in order to avoid inflow of air. The authors have found as much as 40 per cent of air in the mixture drawn into some compressors. In some instances the air is drawn into the rock strata through old and abandoned wells that have not been properly plugged.

Introduction of air of course cuts down gasoline production and may lead the operator into believing that the quality of his gas as regards gasoline content is low. Residual gas may contain so much air as to be objectionable for further use. A determination of the oxygen in the gas as it comes to the plant would give complete information as to the air content. The authors know of few plants where such determinations are made. Oxygen is not a constituent of natural gas as it occurs in the earth. Hence, its presence in a pipe line shows inflow of air. Pure dry air contains 20.93 per cent of oxygen. Consequently, if the oxygen content of a gas is known, the percentage of air can readily be calculated.

CHARACTER AND USES OF RESIDUAL GAS.

In some gasoline plants gas issuing after some of the condensate has been removed is sent to mains and used for consumption in ordinary ways or returned to the leases to be used for pumping purposes. In some plants it is wasted. As far as the quality of most of the gas is concerned, unless greatly contaminated with air, it is superior to that ordinarily used in cities and towns. Originally, as mentioned heretofore, it contains the permanent gases methane and ethane that are also contained in the natural gases ordinarily used for supplying cities. In addition there are contained considerable quantities of the more easily liquefied gases propane and butane, and some gasoline vapors. As the gas passes through the plant the gasoline vapors are to a large extent removed. Some of the propane and butane is liquefied and some of the methane and ethane goes into solution. The proportions of propane, butane, methane, and ethane that disappear may be small. The residual gas as it leaves the plant will contain all of the above-named constituents, because a complete removal of even the gasoline vapors is not accomplished in plant practice. The results of analyses on page 61 show the composition of raw and natural gases before and after passing through the plant. The high heating value of the residual gas is apparent, being in one instance almost twice as high as the heating value of the natural gas of Pittsburgh which has a gross heating value of 1,179 British thermal units per cubic foot at 0° C. and 760 mm. pressure.

Frequently the quantity of gasoline vapors in casing-head gas is so high as to cause trouble in gas-engine cylinders from premature ignition. The fact that casing-head gases vary so widely in composition can not of course be anticipated by engine builders. It is also true that casing-head gases may be unsatisfactory for lighting if mantles are used because the standard burner can not be adjusted for complete combustion of the gas. The result is sooty mantles and imperfect light. Removal of the gasoline vapors sometimes overcomes this objection.

SOLUTION OF GAS IN CONDENSATES.

As previously stated, one of the physical changes occurring in the operation of a gasoline plant has to do with the solution of gas in the condensate, that is, when the residual gas is in contact with the condensate in the storage tank. The following experiment and calculation by the authors will serve to show how small and insignificant this change may be.

A residual gas from an operating plant was shaken with refinery naphtha. The naphtha had a specific gravity of 61° B. The solution was effected at a temperature of 20° C. (68° F.) and atmospheric pressure. The naphtha was shaken with the gas supply until no more gas would go into solution. It was found that 1 liter of the naphtha dissolved 1.760 liters of the gas; or 500 gallons of the naphtha would have dissolved 3,331.7 liters of the gas. If the assumption be made that this residual gas was ethane only, then it can be calculated that 3,331.7 liters of gaseous ethane at 16° C. (60° F.) and 30 inches of mercury is equivalent to 2.7 gallons of liquid ethane. This quantity of liquid is so small as to seem insignificant, although as regards raising the vapor pressure of the condensate it is important.

LIFE OF WELLS AS REGARDS PROFITABLE GASOLINE EXTRACTION.

Some conclusion regarding the length of time that gasoline may be profitably extracted from the natural gas of a given well may be gained by referring to the history of past operations. In the East gasoline-extraction plants have been in operation for several years. An important factor is the quantity of oil present. Neither gas nor oil wells are as long lived in the Mid-Continent as in the Eastern fields. It would appear therefore that in the Mid-Continent field, gasoline operations will not have as long life as those in the Eastern fields. They will probably last longer, however, than those in the California fields. Operations for the recovery of gasoline from casing-head gas in the old Tidioute, Pa., region, where profitable yields of gasoline are obtained at very low pressures, have continued for five years. These wells have been producing gas and oil under vacuum for 40 years prior to the actual installation of gasoline plants. The authors have definite information regarding the installation of a plant at Parkersburg, W. Va., that operates on wells that have been under vacuum for 29 years. After two years' operation of the gasoline plant the quantity of gas began to decline rapidly. General conclusions can not, however, be drawn from this plant.

Around Sisterville, W. Va., there are probably more plants for the recovery of gasoline from casing-head gas than at any other place in the United States. Oil wells in that district have operated under a vacuum for 15 or 20 years. Within the town limits some wells operating under a reduced pressure of 24 inches of mercury produce 1 barrel of gasoline a day. The fact that the engines use city gas, there being no residual gas left, shows the absence of much permanent gas in the wells. Certain oil wells may produce considerable gas when gasoline recovery is started but eventually the gas ceases to flow, and a reduction of pressure withdraws no gas from the well but simply removes the gasoline fractions.

The Glenn pool in the Oklahoma fields has, the authors believe, already shown indications of having a long life. The application of reduced pressure to the wells has increased both the gasoline and the oil yield.

The authors can not predict the life of gasoline-plant operations in general in the Oklahoma fields. With reference to the Glenn pool fields, however, they believe that it would be entirely safe to predict a life of profitable gasoline operation equal to that which can be realized with the oil itself. There are some other regions in Oklahoma that have shown particularly unreliable indications as to casing-head gas, there having been a considerable volume of gas in new wells, which later dwindled rapidly. This tendency seems to be common with the shallow sands, a possible exception being a pool known as the Childer's pool in the Delaware region. When gas escapes freely from wells that have been producing oil for two or three years, they may be expected to produce gas enough to assure the return of the initial investment with profit.

CONDENSATION OF GASOLINE BY REFRIGERATION.

METHODS OF PLANT AT OLINDA, CAL.

In a plant at Olinda, Cal., the gasoline is condensed by refrigeration at low temperatures. Ammonia is the refrigerating agent used. Plate IV, *C*, shows a general view of this plant.

In a letter to the authors, the president of the company stated that in a day of 24 hours 300,000 cubic feet of gas was used, from which was extracted 1,200 gallons of condensate.

Seven condensing coils are used. They are laid side by side and connected to each other by headers. In the first two ammonia refrigeration is not used. A considerable drop of temperature is obtained in these coils, however, by causing the gas to expand into them. The temperature in No. 1 and No. 2 stills is approximately 150° F. (66° C.), in No. 3 still 65° F. (18° C.), in No. 4 still 50° F. (10° C.), in No. 5 still 40° F. (4° C.), in No. 6 still 30° F. (−1° C.), and in No. 7 still 14° F. (−10° C.) The condensate precipitated in the No. 1 still is said to have a specific gravity of about 60° B., in the No. 2 still 62° B., in the No. 3 still 70° B., in the No. 4 still 74° B., in the the No. 5 still 80° B., in the No. 6 still 84° B., and in the No. 7 still 95° B. The condensates are finally all mixed together, producing a mixture with a specific gravity of 80° B.

The company pays 32 cents per pound for ammonia. Approximately 400 pounds was required to charge the machine in September, 1913. Up to March 5, 1914, the charge had not been renewed. The ammonia is delivered to the compressor at a pressure of approximately 15 pounds per square inch, and leaves the compressor at a pressure of 150 pounds.

DESCRIPTION OF ORDINARY AMMONIA REFRIGERATING MACHINE.

An ordinary ammonia refrigerating machine such as is used for cooling purposes in general consists essentially of three parts—a refrigerator or evaporator, a compression pump, and a condenser.

The refrigerator, which consists of a coil or a series of coils, is connected to the suction side of the pump, and the delivery from the pump is connected to the condenser, which is generally of a somewhat similar construction to the refrigerator. The condenser and the refrigerator are joined by a pipe in which is a valve called the regulator. Outside the refrigerating coils is the air, brine, or other substance that is to be cooled in the refrigeration system; and outside the condenser is the cooling medium, which is water. The liquid ammonia passes from the bottom of the condenser through the regulating valve into the refrigerator in a continuous stream. As the pressure in the refrigerator is reduced by the pump and maintained at such a degree as to give the desired boiling point—which is, of course, always lower than the temperature outside the coils—heat passes from the substance outside through the coil surfaces and is taken up by the entering liquid, which is converted into vapor. The vapors thus generated are drawn into the pump, compressed, and discharged into the condenser, the temperature of which is somewhat above that of the cooling water. Heat is transferred from the compressed vapor to the cooling water, and the vapor is converted into a liquid which collects at the bottom and returns by the regulating valve into the refrigerator. The compressor may be driven by a gas engine or in any other convenient manner. The pressure in the condenser varies according to the temperature of the cooling water, and that in the refrigerator is dependent upon the temperature to which the outside substance is cooled.

Anhydrous ammonia is a gas at ordinary temperatures and under atmospheric temperatures. The liquid anhydrous ammonia is commercially sold in iron drums in which it is contained under a pressure varying between 120 and 200 pounds per square inch, the pressure in the drum depending on the temperature of the liquid in it.

Some idea of the nature of the natural-gas condensate obtained can be had by considering the liquefaction points of the constituents that are found in natural gases used for gasoline condensation. The boiling point of liquid propane is −45° C. (−49° F.), and of liquid butane 1° C. (34° F.).

The lowest temperature obtained in the refrigerating coils of the Olinda plant is −10° C. (14° F.). Hence it can be accepted that no propane is liquefied, but some butane and higher paraffins are. The efficiency of the extraction of the condensible constituents from the natural gas for any given temperature will depend upon the velocity of the gas through the coils, or, what is the same thing, the area of cooling surface. Heat is of course extracted from the natural gas when it enters the cooling system. If the cooling area of the pipes is not great enough, the residual natural gas will leave the system still containing gasoline vapors that could have been condensed by further cooling treatment. By proper experimentation the amount of cooling surface required to produce the greatest quantity of salable condensate can be ascertained. Presumably the operators of the Olinda plant have made such a determination. The authors are not closely acquainted with its operations. They believe that the refrigeration method offers much promise and that more plants of this type will be installed.

In the United States at least 85 per cent of the refrigeration plants used for various purposes use ammonia as the refrigerant. Other refrigerants that may be used are sulphur dioxide, carbon dioxide, and water vapor.

TRANSPORTATION OF NATURAL-GAS GASOLINE.

After the production of gasoline from natural gas became a commercial success, the matter of the best methods of transporting it became important. Some of the product when first drawn from the storage tanks may have a specific gravity as high as 100° B. Some condensates are even lighter than this. The exact nature of the product was not clearly understood during the inception of the industry, and in transporting it pressures developed in the containers great enough to burst some of them. Several serious accidents occurred. It was quickly recognized that the material as freshly drawn was not suitable for transportation in containers such as were used for handling ordinary gasoline. Weathering the condensate and blending it with refinery naphtha so that a liquid was obtainable that upon evaporation would not develop excessive pressures overcame the difficulty. However, compulsory rules for its transportation that could be met by the producers were recognized as necessary. Consequently B. W. Dunn, Chief of the Bureau for the Safe Transportation of Explosives, called a meeting of producers at Pittsburgh, Pa., on May 26, 1911. Recommendations were adopted indicating the method of shipping the condensate pending the drafting of final regulations.

Col. Dunn recommended that the producers determine the vapor pressure of their product at 100° F. (38° C.), and sent inspectors to those producers who used tank cars in shipping their product. A tentative maximum vapor pressure was set at 10 pounds per square inch for a temperature of 100° F. (38° C.).

Tank cars differed widely in their construction and many were not suitable for carrying a highly volatile liquid. Consequently, it was recommended that only standard tank cars should be employed.

RULES OF THE INTERSTATE COMMERCE COMMISSION.

The final rules of the Interstate Commerce Commission regarding the shipment of natural-gas gasoline are presented below.

REGULATIONS FOR THE TRANSPORTATION ON RAILROADS OF NATURAL-GAS GASOLINE.[a]

Liquefied petroleum gas is a condensate from the "casing-head gas" of petroleum oil wells, whose vapor tension at 100° F. (38° C.) (90° F.—32° C.—November 1 to March 1) exceeds 10 pounds per square inch. Liquefied petroleum gas must be shipped in metal drums or barrels which comply with "Shipping-Container Specifications No. 5," or in tank cars especially constructed and approved for this service by the Master Car Builders' Association.

When the vapor tension at 100° F. (38° C.) exceeds 25 pounds per square inch, cylinders as prescribed for compressed gas must be used.

(The commission has not deemed it best at this time to prohibit the use of good wooden barrels in shipping inflammable liquids with a flash point below 20° F. (—7° C.). It is, however, expected that their use for that purpose will be gradually discontinued and that within a reasonable time metal barrels will come into general use for such shipments.)

Packages containing inflammable liquids must not be entirely filled. Sufficient interior space must be left vacant to prevent distortion by containers when heated to a temperature of 120° F. (49° C.). This vacant space must not be less than 2 per cent of the capacity of the container, including the dome capacity of tank cars.

1. The provisions of "Shipping-Container Specifications No. 5" apply to all containers specified therein that are purchased after December 31, 1911, and used for the shipment of dangerous articles other than explosives. Each such container purchased subsequently to December 31, 1911, shall have plainly stamped thereon the date of manufacture thereof.

2. An iron or steel barrel or drum with a capacity of from 50 to 55 gallons must have a minimum weight in the black, exclusive of the weight of rolling hoops, of 70 pounds, and the minimum thickness of metal in any part of the completed barrel must not be less than that of No. 16 gage United States standard.

3. An iron or steel barrel or drum with a capacity of from 100 to 110 gallons must have a minimum weight in the black, exclusive of the rolling hoops, of not less than 130 pounds, and the minimum thickness of metal in any part of the completed barrel or drum must not be less than that of full No. 14 gage United States standard.

4. Each barrel or drum must stand without leaking a manufacturers' test under water by interior compressed air at a pressure of not less than 15 pounds per square inch sustained for not less than two minutes, and the type of barrel or drum must be capable of standing without any serious permanent deformation and without leaking a hydrostatic test pressure of not less than 40 pounds per square inch, sustained for not less than five minutes.

5. When filled with water to 98 per cent of its capacity, the type of barrel or drum must also be capable of standing without leakage a test drop on its chime for a height of 4 feet upon a solid concrete foundation.

6. Bungs and other openings must be provided with secure closing devices that will not permit leakage through them. Threaded metal plugs must be close fitting. Gaskets must be made of lead, leather, or other suitable material. Wooden plugs must be covered with a suitable coating and must have a driving fit into a tapered hole.

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[a] From "Regulations of the Interstate Commerce Commission for the Transportation of Explosives and Other Dangerous Articles by Freight and by Express, and Specifications for Shipping Containers," published by the Bureau for the Safe Transportation of Explosives and Other Dangerous Articles, in January, 1912, pp. 72, 143, 144, and 145. Effective Mar. 31, 1912.

7. The method of manufacturing the barrel or drum and the materials used must be well adapted to producing a uniform product. Leaks in a new barrel or drum must not be stopped by soldering, but must be repaired by the method used in constructing the barrel or drum.

BLENDING GASOLINE WITH NAPHTHA.

In the foregoing pages the word "gasoline" has been loosely applied by the authors to mean the liquid obtained from natural gas subjected to treatment. The term has been retained because it has become a trade name. The term "condensate" would be more suitable, because the liquid first obtained is usually so volatile that it comes quite outside the meaning that is usually applied to the term gasoline. The refinery gasoline as prepared for the trade is not a definite compound, nor is the natural-gas condensate, as it is collected in storage tanks before it is prepared for market. After this preparation, if properly done, natural-gas condensate comes under the same category as refinery gasoline.

At present practically all natural-gas condensate is mixed with lower grade refinery naphthas. This process constitutes the so-called blending. In the early days of the industry the handling of the natural-gas condensate involved its weathering or the evaporation of its light constituents until a product was obtained that could be used as refinery gasoline is ordinarily used and could be safely transported under rules promulgated by the Bureau for the Safe Transportation of Explosives. By the process of "weathering" a loss of material as much as 60 or 70 per cent of the total quantity frequently occurred. Sometimes the loss was even greater. By the process of blending a product is obtained that has a slower rate of evaporation than the natural-gas condensate used in making the blend.

COMMERCIAL NAMES OF DISTILLATION PRODUCTS FROM CRUDE OIL.

Below is presented a table showing the commercial names of different grades of naphthas, gasolines, kerosenes, etc., their gravities, boiling points, and the chemical names of the constituents that comprise them:

Data regarding distillation products of crude oil.

Name of product.	Gravity.	Boiling point.	Constituents.
	°*B.*	°*C.*	
Cymogene	108	0	Chiefly butanes.
Rhigolene	92-94	18	Chiefly butanes and pentanes.
Petroleum ether	80-94	70-90	Chiefly pentanes and hexanes.
Naphtha	58	90-120	Chiefly hexanes, heptanes, and octanes.
Benzine		120-150	Chiefly octanes and nonanes.
Kerosene	48		
Vaseline			
Solid paraffin			

DISCUSSION OF THE PRODUCTS.

According to this table, any condensate having a gravity of 94° to 108° B. will contain a large proportion of pentane and butane. Probably most of the condensate having a gravity of 108° B. will be butane and most of that having a gravity of 94° B. will be pentane, although a certain proportion of each will consist of the heavier constituents, among which will be those of ordinary gasoline. Butane and pentane have boiling points of 0° C. (32° F.) and 36° C. (97° F.), respectively. These temperatures (especially that of butane) are below ordinary atmospheric temperature; hence a rapid loss of these constituents in a natural-gas condensate will occur when the condensate is exposed to the air.

Rhigolene, it will be noticed, consists chiefly of butane and pentane. The boiling point of rhigolene is given as 18° C. (64° F.). This boiling temperature is midway between that of butane and pentane. Most natural-gas condensates have a gravity of 80° to 94° B. Such a mixture is classified as petroleum ether in the above scale. This scale has reference to refinery products. Such mixtures are of a more uniform composition than natural-gas condensates that are freshly drawn from accumulator tanks, whereas petroleum ether may be a mixture that contains chiefly pentane and hexane and will not boil when freshly prepared, yet natural-gas condensates, especially those of the higher gravity, may boil violently. The ebullition is probably due chiefly to the escape of butane and some propane. In the natural-gas condensate there will be more of these constituents and less of the pentane and hexane. There will also be some of the still higher liquid paraffins and some of the dissolved gases methane and ethane. The above table, as far as the intermediate members are concerned, can scarcely be applied to natural-gas condensates, because the latter are of a more complex composition. It is inserted here only because its use brings out several instructive points. Probably the above classification is little used in the trade. Different trade names for practically the same distillates from petroleum are used by different refiners.

EVAPORATION LOSSES IN BLENDING.

The following tables (Tables 6 to 9) show the results of some blending tests made by the authors. The condensate as it was drawn from the storage tank was allowed to stand in graduated vessels, and the loss sustained by evaporation over different periods of time was noted. The containers were graduated glass cylinders having a capacity of 1,000 c. c. Their inside diameter was 2¾ inches and they were 13 inches high. Some of the same condensate, as it was drawn from the storage tanks, was also mixed with naphtha and allowed to stand and the loss noted.

TABLE 6.—*Evaporation losses*[a] *of natural-gas condensate from plant A when allowed to stand exposed to the air.*

Test No.	Gravity of gasoline.	Temperature of gasoline at start.		Temperature of outside air.		End of 1 hour.				End of 2 hours.		End of 3 hours.		End of 18 hours.		End of 24 hours.	
						Loss.	Specific gravity.	Temperature.		Loss.	Specific gravity.	Loss.	Specific gravity.	Loss.	Specific gravity.	Loss.	Specific gravity.
	° *B.*	° *F.*	° *C.*	° *F.*	° *C.*	*P. ct.*	° *B.*	° *F.*	° *C.*	*P. ct.*	° *B.*	*P. ct.*	° *B.*	*P. ct.*	° *B.*	*P. ct.*	° *B.*
1	82.5	20	− 6.7	60	16	4.5	81	50	10	8.5	80.0	9.5	80.0	18.0	78.0	......	.....
2	88.0	8	−13	......	......	......	......	......	......	......	......	......	......	25.0	82.0	......	.....
3	88.5	......	......	60	16	8.0	88	54	12	10.0	87.5	13.0	87.0	25.0	82.0	......	.....
4	94.0	0	−18	60	16	12.0	90	38	3	22.0	89.5	26.0	88.5	......	......	......	.....
5	95.0	0	−18	54	12	19.0	92	......	......	......	......	40.0	88.0	......	......	53.0	84.5
6	96.0	5	−15	55	13	24.0	92	30	1	33.0	91.0	......	......	......	......	50.0	84.0
7	100.0	10	−12	55	13	......	......	25	−4	......	......	......	......	54.0	89.5	......	.....

[a] Computed from original volume of condensate.

TABLE 7.—*Evaporation losses of natural-gas condensate from plants B and C when allowed to stand exposed to the air.*

PLANT B.

Test No.	Specific gravity of gasoline.	Temperature of gasoline.		Temperature of outside air.		End of 24 hours.	
						Loss.	Specific gravity.
	° *B.*	° *F.*	° *C.*	° *F.*	° *C.*	*P. ct.*	° *B.*
1	69	40	4	50	10	8	69
2	88	30	−1	50	10	25	87

PLANT C.

Test No.	Specific gravity of gasoline.	Temperature of gasoline.		End of 10 hours.	
				Loss.	Specific gravity.
	° *B.*	° *F.*	° *C.*	*P. ct.*	° *B.*
1	75.5	30	− 1	6.5	73.5

TABLE 8.—*Evaporation losses of natural-gas condensate from plant A mixed with refinery naphtha.*

Test No.	Proportions in mixture.		Specific gravity of—		Specific gravity of mixture.	Temperature of mixture.		End of 5 hours.		End of 18 hours.		End of 24 hours.	
	Gasoline.	Naphtha.	Gasoline.	Naphtha.				Loss.	Specific gravity.	Loss.	Specific gravity.	Loss.	Specific gravity.
	P. ct.	*P. ct.*	° *B.*	° *B.*	° *B.*	° *F.*	° *C.*	*P. ct.*	° *B*	*P. ct.*	° *B.*	*P. ct.*	° *B.*
1	70	30	87	57	77	......	......	......	......	......	......	25	70
2	50	50	92	57	73	......	......	......	......	......	......	62	66
3	70	30	94	57	81	......	......	27	75	......	......	36	72
4	73	27	93	57	83	10	−12	22	......	......	......	44	......
5	70	30	96	57	81	......	......	......	......	......	......	62	71
6	50	50	94	48	77	......	......	......	......	64.0	55	......	......
7	70	30	92	48	74	......	......	28	69	......	......	43	66
8	80	20	93	48	83	15	− 9	......	......	32	73	......	......

TABLE 9.—*Evaporation losses of different mixtures of natural-gas condensates and refinery naphthas.*

Test No.	Proportions in mixture.		Specific gravity of—		Specific gravity of mixture.	End of 1 hour.		End of 2 hours.		End of 3 hours.		End of 4 hours.	
	Condensate.	Naphtha.	Condensate.	Naphtha.		Specific gravity.	Loss.	Specific gravity.	Loss.	Specific gravity.	Loss.	Specific gravity.	Loss.
	P. ct.	*P. ct.*	°*B.*	°*B.*	°*B.*	°*B.*	*Per ct.*	°*B.*	*Per ct.*	°*B.*	*Per ct.*	°*B.*	*Per ct.*
1.....	50	50	93	60	76.5	76	4	75	10	75	12	74	16
2.....	70	30	93	44	76	75.5	6	74.5	14	73.5	20	72.5	24
3[a]....	70	30	95	44	74.5	74	13	72.5	20	72	26	71.5	29
4[a]....	50	50	95	44	67	65.5	8	65	16	64	20	64	22

Test No.	Proportions in mixture.		Specific gravity of—		Specific gravity of mixture.	End of 5 hours.		End of 6 hours.		End of 7 hours.		End of 24 hours.		Temperature of atmosphere.	
	Condensate.	Naphtha.	Condensate.	Naphtha.		Specific gravity.	Loss.	Specific gravity.	Loss.	Specific gravity.	Loss.	Specific gravity.	Loss.		
	P. ct.	*P. ct.*	°*B.*	°*B.*	°*B.*	°*B.*	*P. ct.*	°*B.*	*P. ct.*	°*B.*	*P. ct.*	°*B.*	*P. ct.*	°*F.*	°*C.*
1.....	50	50	93	60	76.5	74	18	73	22	70.5	31	67	43	65 to 70	18 to 21
2.....	70	30	93	44	76	71.5	29	71	30	......	......	......	......	......	......
3[a]....	70	30	95	44	74.5	71	30	69	34	68.5	37	65	50	60 to 70	16 to 21
4[a]....	50	50	95	44	67	63	25	62	30	61	36	56	54	60 to 70	16 to 21

[a] In conducting this test the mixture was exposed to the atmosphere to a greater extent than in tests 1 and 2. It was poured from one vessel to another eight times, thus exposing more liquid surface to the atmosphere and causing more rapid evaporation than would have occurred if it had been allowed to remain in the same vessel all the time without disturbance.

REMARKS ON TABULATED DATA.

As regards the results shown in Table 6, the condensate was exposed to the air in the graduated glass cylinders already mentioned.

The pressure exerted on the natural gas in making the condensate varied between 140 and 200 pounds per square inch. The storage tank was so arranged that after each test the entire volume of condensate could not be removed in order to provide an empty tank for a succeeding test. Hence, the condensate from one test was always mixed with some condensate from a preceding test. For this reason the exact pressure that was exerted on the gas for any particular test is not recorded here. A gas meter was not connected to the "plant," so that the quantity of gas used in making the condensate could not be measured.

It will be observed that as the gravity of the condensates increased the losses by evaporation also increased, ranging from 4.5 per cent to 24 per cent at the end of one hour, from 8.5 to 33 per cent at the end of two hours, from 9.5 to 40 per cent at the end of three hours, and as much as 53 and 54 per cent at the end of 24 hours and 18 hours.

The condensate used in test 1 started to boil slightly when first drawn from the storage tank and continued to do so for two hours.

This boiling was probably due mainly to the liquid butane present in the mixture changing to the gaseous condition. Butane boils at 1° C. (34° F.), and when exposed to the temperature of this particular condensate, which was 20° F. (−7° C.), the liquid of course changed to the gaseous condition. A small part of the gaseous butane remained dissolved in the condensate, but the proportion that could not be held in solution escaped.

The condensate used in test 3 lost 8 per cent by evaporation during the first hour and 13 per cent at the end of three hours; at the end of 18 hours 25 per cent of the original mixture had evaporated. The original condensate must have contained considerable quantities of butane and pentane to account for such a loss. Most of the butane was probably eliminated during the first two hours, and then a much slower evaporation of the other constituents, principally pentane, followed.

The condensate used in test 7 was a very volatile product, being nearly the lightest gasoline obtained in the plant operation.

The results mentioned above are presented to show actual losses sustained at the particular plants where the tests were conducted under certain conditions--that is, exposure of the condensates to atmospheric pressure and temperatures in certain forms of containers.

The total loss through evaporation was not exactly determined. This total loss includes the losses shown in the above tables plus that sustained when the condensate was removed from the storage tank. As soon as the valve on the storage tank was opened and the condensate came in contact with the outside air in flowing to the graduated vessel provided to catch it, the evaporation commenced; hence some loss of liquid occurred before the condensate could be measured in the vessel provided to receive it. The storage tank was provided with a glass gage which showed the height of the liquid therein. As the liquid was drawn from the tank its level, of course, fell in the gage. By noting this level before and after some of the liquid from the tank had been drawn into the graduated glass vessel, the loss of liquid occurring could be approximately determined. The loss amounted to about 10 per cent, and was of course due principally to the volatilization of the liquid gases. This loss is to be added to the losses shown in the preceding table in order to get the total loss.

In Tables 7 and 8 are shown the evaporation losses that resulted when freshly drawn condensate from plants B and C were allowed to stand exposed to the atmosphere for 10 and 24 hours. The losses shown are much smaller than those from plant A. This result is to be expected, because more of the heavier paraffin hydrocarbons were contained in the condensates. The temperatures of the freshly drawn condensates were also higher than the temperature of the condensate obtained at plant A. Hence the constituents present in the condensate had higher boiling points and evaporated more slowly.

The condensate represented by test 2 (Table 7) was obtained when the pressure on the natural gas was 210 pounds per square inch. The liquid did not boil when withdrawn from the tank, although a bubble of gas would occasionally issue during the first hour of exposure. Hence the condensate probably contained only a small quantity of liquid butane. Likewise the proportion of pentane must have been smaller than in the condensates obtained from plant A.

The condensates represented in Tables 7 and 8 were obtained from different plants than those represented in Table 6. The pressures employed were practically the same, yet the character of the condensates differed. For instance, all of the condensates obtained in the tests conducted at plant A would boil more or less at first, owing to escaping gas. Those obtained at plants B and C bubbled only a little. This difference was largely due to differences in the composition of the natural gases used at the plants.

In Table 9 are shown the results of blending natural-gas condensate (specific gravity 48° B.) from plant A (Table 1) with naphtha having a specific gravity of 57° B. The percentages of losses are calculated to percentage losses of the natural-gas condensate and not of the mixture.

The conditions under which these tests were conducted would not warrant definite conclusions regarding the decrease of evaporation rate to be effected by blending. However, the losses after blending were still large.

If the evaporation loss were to be calculated to the percentage loss of the mixture of condensate and naphtha the percentage of losses on the blends would be much reduced, but the figures so obtained would not show the true loss of condensate. Some experimenters have probably done this and misled themselves into believing that the percentage so calculated represented the actual loss of condensate. The authors calculated the blending losses by throwing the loss wholly on the condensate. They determined by experiment that the evaporation loss of the refinery naphtha used in making the blends was so small as to be inappreciable as compared to condensate losses.

RESULTS OF EVAPORATION TESTS IN WEST VIRGINIA.

Table 10, following, shows the evaporation losses when natural-gas condensates from a different plant than those mentioned previously had been exposed to the atmosphere. The evaporation losses shown in the preceding tables occurred at plants along the Allegheny River near the New York State line. The tests represented in the table following were made at a plant in West Virginia. Plant operations were so conducted as regards pressures that condensates of different specific gravities were obtained. The condensates were allowed to evaporate in graduated glass cylinders of the same form as those used in the tests covered by Tables 6 to 9.

TABLE 10.—*Evaporation losses of condensates from the same plant, but of different specific gravities.*

Test No.	Gravity of condensate at start.	Temperature of condensate at start.		End of 1st hour.		End of 2 hours.		End of 3 hours.		End of 4 hours.		End of 5 hours.	
				Gravity.	Loss.	Gravity.	Loss.	Gravity.	Loss.	Gravity.	Loss.	Gravity.	Loss.
	°*B.*	°*F.*	°*C.*	°*B.*	*Per cent.*	°*B.*	*Per cent.*	°*B.*	*Per cent.*	°*B.*	*Per cent.*	°*B.*	*Per cent.*
1......	79	35	2	79	0	79	0	79	1	78.5	2	78.5	2
2......	81.5	20	− 7	81	2	81	4	80	9	79.5	13	79	16
3......	93	0	−48	93	9	92.5	21	92	27	91	33	90.5	35
4......	94	0	−18	93.5	15	93.5	20	93	25	93	29	92.5	30
5......	94.5	8	−13.3	94	13	93.5	24	93	28	92	34	91.5	35
7......	95.0	5	−15	....	17	91	25	89.5	34	89	38	88	42
8......	96.0	5	−15	93	19	92	26	90.5	31	90	37	90	40
9......	98.0	15	− 9.4	97	11	96	19	95	24	94.5	26	94.5	29
10......	83.5	18	− 8	....	......	83.5	3	83	4	82.5	6	82.0	7

Test No.	Gravity of condensate at start.	Temperature of condensate at start.		End of 6 hours.		End of 7 hours.		End of 8 hours.		End of 24 hours.		Temperature of atmosphere.	
				Gravity.	Loss.	Gravity.	Loss.	Gravity.	Loss.	Gravity.	Loss.		
	°*B.*	°*F.*	°*C.*	°*B.*	*Per cent.*	°*B.*	*Per cent.*	°*B.*	*Per cent.*	°*B.*	*Per cent.*	°*F.*	°*C.*
1......	79	35	2	78	3	78	4	78	4	77	10	55 to 60	13 to 16
2......	81.5	20	− 7	79	18	78.5	20	......	......	74.5	31	60 to 65	16 to 18
3......	93	0	−48	90	40	89.5	41	89	43	87.5	50	60 to 70	16 to 21
4......	94	0	−18	92	33	91.5	34	91.5	35	89.5	45	55 to 60	13 to 16
5......	94.5	8	−13.3	91	36	90.5	37	......	......	88.5	44	50 to 60	10 to 16
7......	95.0	5	−15	87.5	45	87	48	......	......	......	65	60 to 65	16 to 18
8......	96.0	5	−15	90	42	89.5	45	89.5	46	86	53	60 to 62	16 to 17
9......	98.0	15	− 9.4	94	30	94	31	94	32	92.5	43	40 to 50	4 to 10
10......	83.5	18	− 8	82	9	81	13	81	15	80	25	40 to 50	4 to 10

Table 11, following, shows results obtained when mixtures of natural-gas condensate and refinery naphtha were exposed to the air and allowed to evaporate. The tests were made at the same plant as the tests covered by Table 10, and with the same condensates.

TABLE 11.—*Evaporation losses of mixtures of natural-gas condensates and refinery naphthas.*

Test No.	Proportions in mixture.		Specific gravity of—		Specific gravity of mixture.	End of 1 hour.		End of 2 hours.		End of 3 hours.		End of 4 hours.		End of 5 hours.	
	Condensate.	Naphtha.	Condensate.	Naphtha.		Specific gravity.	Loss.	Specific gravity.	Loss.	Specific gravity.	Loss.	Specific gravity.	Loss.	Specific gravity.	Loss.
	P. ct.	*P. ct.*	°*B.*	°*B.*	°*B.*	°*B.*	*P. ct.*	°*B.*	*P. ct.*	°*B.*	*P. ct.*	°*B.*	*P. ct.*	°*B.*	*P. ct.*
1....	50	50	98	60	76	76	10	76	12	76	16	76	18	76	20
2....	70	30	98	60	86	86	7	84.5	13	84	17	84	20	83.5	23
3....	70	30	97	60	84	83	14	81.5	20	81	23	80	29	80	30
4....	50	50	97	60	76	75	4	74	6	73.5	12	73	16	73	17
5....	50	50	95	60	76	75.5	4	75	10	74	15	74	18	74	20
6[a]...	50	50	95	60	77	76.5	5	74	24	72.5	36	71.5	46	70	54
7....	70	30	95	60	84.5	83	11	82	19	81.5	21	81	26	80	27
8[a]...	70	30	95	60	83.5	83	10	81.5	17	80.5	23	79	27	78.5	30
9....	60	40	95	60	80.5	79.5	8	79	15	78.5	18	77.5	22	77.5	23
10....	70	30	95	60	84	82.5	10	81	17	80.5	21	79.5	24	79	27
11....	70	30	83.5	60	74.5	74.5	0	74.5	0	74.5	1	74	3	74	7
12....	70	30	93.5	44	76.5	75	10	74.5	14	74	19	73	21	72.5	23

[a] Test conducted in a shallow pan, 8 inches in diameter and 1 inch deep.

TABLE 11.—*Evaporation losses of mixtures of natural-gas condensates and refinery naphthas*—Continued.

Test No.	Proportions in mixture.		Specific gravity of—		Specific gravity of mixture.	End of 6 hours.		End of 7 hours.		End of 8 hours.		End of 24 hours.		Temperature of atmosphere.	
	Condensate.	Naphtha.	Condensate.	Naphtha.		Specific gravity.	Loss.	Specific gravity.	Loss.	Specific gravity.	Loss.	Specific gravity.	Loss.		
	P. ct.	*P. ct.*	*°B.*	*°B.*	*°B.*	*°B.*	*P. ct.*	*°B.*	*P. ct.*	*°B.*	*P. ct.*	*°B.*	*P. ct.*	*°F.*	*°C.*
1...	50	50	98	60	76	75.5	22	75.5	23	.....	.....	73	38	40 to 50	4 to 10
2...	70	30	98	60	86	83	24	83	26	83	27	80	40	40 to 50	4 to 10
3...	70	30	97	60	84	79.5	33	79	37	79	39	76	47	60 to 70	16 to 21
4...	50	50	97	60	76	73	20	72.5	20	.....	.....	69	38	60 to 70	16 to 21
5...	50	50	95	60	76	73.5	22	73.5	24	.....	.....	70.5	40	60 to 70	16 to 21
6[a]..	50	50	95	60	77	69	60	.....	.....	.....	.....	65	96	60 to 70	16 to 21
7...	70	30	95	60	84.5	80	29	80	29	.....	.....	77	33	60 to 70	16 to 21
8[a]..	70	30	95	60	83.5	77.5	34	77	39	.....	.....	70	63	50 to 60	10 to 16
9...	60	40	95	60	80.5	77.5	25	77	27	.....	.....	74	38	50 to 60	10 to 16
10...	70	30	95	60	84	79	29	78.5	31	.....	.....	75.5	43	60 to 70	16 to 21
11...	70	30	83.5	60	74.5	73.5	9	73	10	.....	.....	71	19	55 to 60	13 to 16
12...	70	30	93.5	44	76.5	72	24	72	27	.....	.....	68	39	50 to 60	10 to 16

[a] Test conducted in a shallow pan, 8 inches in diameter and 1 inch deep.

DISCUSSION OF RESULTS SHOWN IN TABLES 8 TO 11.

As shown in Table 10 the losses when condensates of gravities between 79° and 98° B. were exposed to the atmosphere were as follows: One hour, 0 to 19 per cent; 2 hours, 0 to 26 per cent; 3 hours, 1 to 34 per cent; 4 hours, 2 to 38 per cent; 5 hours, 2 to 42 per cent; 6 hours, 3 to 45 per cent; 7 hours, 4 to 48 per cent; 8 hours, 4 to 46 per cent; and for 24 hours, 10 to 65 per cent. At the end of 24 hours the temperatures of the condensates were practically the same as the temperature of the atmosphere.

If tests 1 and 2, Table 10, be excepted, the largest losses occurred during the first hour and the rate of evaporation gradually decreased. This is to be expected. Most of the material that first evaporated was liquid butane. Liquid butane boils at 1° C. (34° F.); hence it would evaporate rapidly. The rate of evaporation of the pentanes and hexanes is, of course, much slower. The curves shown elsewhere clearly illustrate these points.

Table 11 shows the evaporation losses when the natural-gas condensates were mixed with refinery naphthas and allowed to evaporate. The rate of evaporation for tests 1 and 2 (Table 11) are almost the same, but slightly slower than of test 9 (Table 10), which represents the evaporation loss when the condensate alone was allowed to evaporate. The difference is especially noticeable at the end of the second hour, being 19 per cent as against 12 and 13 per cent. The rates are not widely different for the remaining period, but still noticeable. Tests 3, 4, 5, 7, and 9, Table 11, may be compared to tests 4, 5, 6, 7, and 8, Table 10. In the former when condensates alone were allowed to evaporate the losses for the first hour ranged from 13 to 19 per cent. When condensates of approximately the same specific gravity were mixed with naphtha and allowed to evaporate, the losses for the first hour ranged from 4 to 14 per cent.

DIFFERENCE IN EVAPORATION RATES OF MIXTURES.

The difference in the evaporation rates, shown for the mixtures, is marked all through the tests. The following tabulation clearly brings out this variation:

Evaporation losses of condensates and "blends" for periods ranging from 1 to 24 hours.

	Loss in 1 hour.	Loss in 2 hours.	Loss in 3 hours.	Loss in 4 hours.	Loss in 5 hours.	Loss in 6 hours.	Loss in 7 hours.	Loss in 24 hours.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Condensates [a]........	11 to 19	19 to 26	25 to 34	26 to 38	29 to 42	30 to 45	31 to 48	43 to 65
"Blends"............	4 to 14	6 to 19	12 to 23	16 to 29	17 to 30	20 to 33	24 to 39	33 to 47

[a] Specific gravities, 94° to 98° B.

In the tests represented in the foregoing table for all of the "blends," condensates with specific gravities of 94° to 98° B. were used. However, Table 11 shows that in preparing the "blends," different amounts of the condensate were used for different tests. In some of the tests the "blends" were prepared by mixing the condensates and naphtha in equal proportions. In others, the proportions were 70 per cent of condensate and 30 per cent of naphtha; in others, 60 and 40. Table 11 shows that the evaporation rates were slower when the smaller quantities of condensate were used, as was to be expected.

COMPARATIVE EVAPORATION LOSSES OF MIXTURES AND CONDENSATES.

Table 12 shows the evaporation losses when the condensates alone were exposed to the atmosphere and when the condensates were mixed in various proportions with the naphtha. This table was compiled from the results of tests 1, 2, 3, 4, 5, 9, 10, and 12, Table 11, and tests 3, 4, 5, 7, 8, and 9, Table 10.

TABLE 12.—*Comparative evaporation losses of blends prepared by mixing different proportions of condensate and naphtha and of condensate alone.*

Test No.	Table No.	Proportions in mixtures.		Specific gravity of—		Specific gravity of mixture.	Loss at end of—								
		Condensate.	Naphtha.	Condensate.	Naphtha.		1 hour.	2 hours.	3 hours.	4 hours.	5 hours.	6 hours.	7 hours.	8 hours.	24 hours.
		P. ct.	*P. ct.*	*°B.*	*°B.*	*°B.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1.......	11	50	50	98	60	76	10	12	16	18	20	22	23	......	38
2.......	11	70	30	98	60	86	7	13	17	20	23	24	26	27	40
4.......	11	50	50	97	60	76	4	6	12	16	17	20	20	......	38
3.......	11	70	30	97	60	84	14	20	23	29	30	33	37	39	47
9.......	10	100	0	98	......	......	11	19	24	26	29	30	31	32	43
8.......	10	100	0	96	......	......	19	26	31	37	40	42	45	46	53
5.......	11	50	50	95	60	76	4	10	15	18	20	22	24	......	40
7.......	11	70	30	95	60	84.5	11	19	21	26	27	29	29	......	33
10......	11	70	30	95	60	84	10	17	21	24	27	29	31	......	43
5.......	10	100	0	94.5	......	......	13	24	28	34	35	36	37	......	44
4.......	10	100	0	94.0	......	......	15	20	25	29	30	33	34	35	45
7.......	10	100	0	95.0	......	......	17	25	34	38	42	45	48	......	65
12......	11	70	30	93.5	44	76.5	10	14	19	21	23	24	27	......	39
3.......	10	100	0	93	......	......	9	21	27	33	35	40	41	43	50
11......	11	70	30	83.5	60	74.5	0	0	1	3	7	9	10	......	39
2.......	10	100	0	81.5	......	......	2	4	9	13	16	18	20	......	31

The slower rates of evaporation of the mixtures of condensates and naphtha as compared to those of the condensates alone follow from the fact that if two liquids dissolve each other in all proportions, and if they have widely different vapor pressures and boiling points, the vapor pressure of the mixture frequently falls between the vapor pressures of the components, and the boiling point of the mixture falls between the boiling points of the components. The more volatile liquid evaporates principally, at first, during the distillation, the less volatile liquid remaining behind, so that by a repetition of the process the two may be more or less completely separated. As evaporation continues a mixture is finally left that contains components whose boiling points and vapor pressures lie near together.

FACTORS AFFECTING RATE OF EVAPORATION.

Attention should be called to the higher evaporation rates of tests 3 and 4, Table 9, as compared to tests 1 and 2, Table 9. Tests 3 and 4 were conducted in shallow pans, whereas tests 1 and 2 were conducted in tall narrow cylinders. For a given temperature, other things being equal, tho rate of evaporation is almost proportional to the area of the surfaco of the liquid.

In actual operation different evaporation losses will be sustained than those mentioned above, depending upon the shape of the container that is used for holding the liquid when the latter is exposed to the air. If the mixture be placed in a drum such as is ordinarily used for transporting natural-gas gasoline, and the bunghole left open there will occur a much slower rate of evaporation than if the entire surface of the liquid be exposed to the air by means of an opening, say, as large as the area of the liquid.

In the former case the rate of evaporation will approach evaporation conditions in a closed space. In a closed chamber evaporation will take place more or less rapidly at first. After some time, however, the space above the liquid will become partly filled with stray molecules that have escaped through the surface film. These, after escape, move about indiscriminately in the chamber and are reflected from its walls and from each other. Some return to the liquid, and once they fall on its surface they may be attracted into the interior. It thus happens that a certain stage is ultimately attained at which as many molecules return to the liquid per second as leave it and an equilibrium is established; at this stage evaporation may be said to have ceased. There is no further loss to the liquid or gain to the vapor outside it; there is, however, a continual exchange going on, new molecules are being continually projected from the surface and others are falling into the liquid in equal numbers. The chamber is then said to be filled with saturated vapor, or the vapor is said to be saturated; in any stage before this final stage has been reached the vapor is said to be nonsaturated. A saturated vapor is thus one that is in equilibrium with its own liquid.

If there is any means of escape, however, as from the bunghole of the drum, some of the molecules, in wandering about inside the drum, will make their exit through the bunghole and into the atmosphere, never returning to the liquid. There will be thus a continual flow of molecules from the surface of the liquid to the atmosphere, and evaporation will continue in this manner at a steady rate as long as the temperature is maintained constant. If the area of the hole be expanded to the size of the surface of the liquid, much faster evaporation will take place, because there will be a much wider avenue of escape opened for the wandering molecules.

When natural-gas condensates or any liquids are exposed to the air, as in transferring the condensates from accumulator tanks to storage tanks or to drums, evaporation takes place much more rapidly than when the condensate is lying quietly in the container. This increased rate results from the much greater surface of the liquid that is exposed to the air.

The authors of this publication found that from 2,040 gallons of condensate transferred from a storage tank to a loading station at a railroad siding by means of a pipe line 1,500 feet long, there was lost by evaporation 747 gallons, or 36 per cent. This loss occurred at the plant at which the tests shown in Tables 10 and 11 were conducted. The material was allowed to run down the pipe line by gravity to the loading stations. This experiment shows that evaporation rates may be much faster than in the tests conducted by the authors in glass cylinders. Evaporation losses may be also hastened when the atmospheric temperature is high. The atmospheric temperature, when the authors conducted the tests, ranged from 40° to

70° F. (4° to 21° C.), but most of the time the temperature ranged between 50° and 60° F. (10° to 16° C.). During the summer time temperatures are much higher and evaporation losses will be correspondingly greater. In colder weather they would be smaller.

CURVES SHOWING EVAPORATION LOSSES.

The authors have plotted certain curves to show the evaporation losses resulting when natural-gas condensates and mixtures of condensates and naphtha are exposed to the air. The curve results shown in figure 11 are plotted from data from Table 10. It will be observed that the rate of evaporation of condensates of high specific gravity is rapid for the first eight hours. The rate of evaporation of a condensate with a specific gravity of 79° B. is fairly uniform. A condensate with a specific gravity of 98° B. underwent a slower rate of evaporation than four condensates of lower specific gravity. This difference was probably due in part to the fact that during the tests

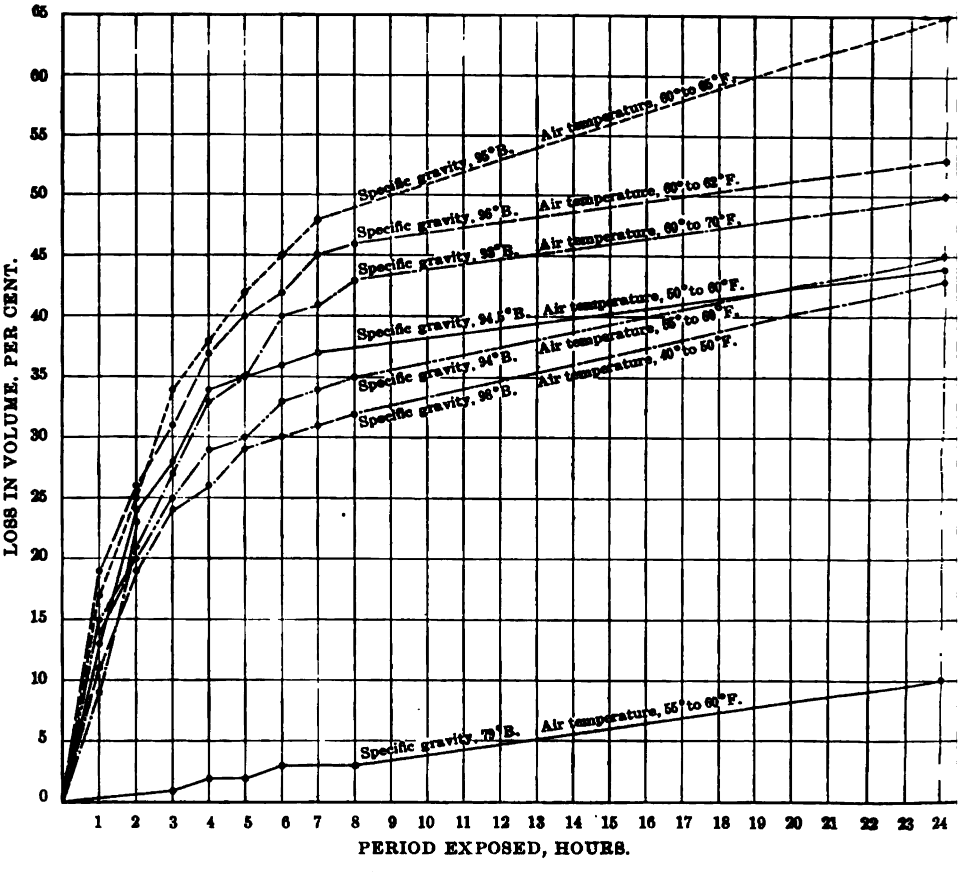


FIGURE 11.—Evaporation losses of natural-gas condensates.

of condensates of high specific gravity the temperature of the atmosphere was about 10° F. (6° C.) lower.

In figure 12 are shown the evaporation losses that resulted when two natural-gas condensates, with gravities of 98° and 83.5° B., were mixed with naphtha in different proportions. The curves were prepared from Tables 10 and 11.

Figure 13 shows the evaporation losses resulting when a condensate with a specific gravity of 93° B. was exposed to the air and when it was mixed with naphtha. The curves were prepared from Table 9.

Figure 14 shows the evaporation losses when a condensate, with a specific gravity of 95° B., was exposed to the air and when it was mixed with naphthas of different specific gravities and exposed. Smaller losses resulted when a naphtha with a specific gravity of 60° B. was used than when a naphtha with a specific gravity of 44° B. was used.

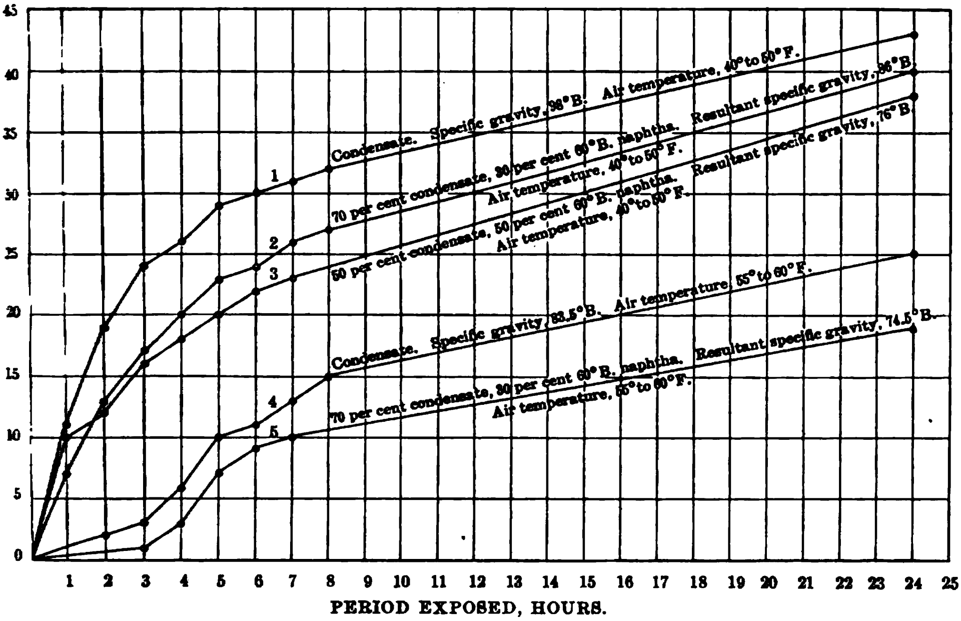


FIGURE 12.—Evaporation losses when two natural-gas condensates were mixed with naphtha in different proportions.

VAPOR-PRESSURE TESTS.

Figures 15, 16, 17, and 18 show the results of tests made by the authors to determine the pressures exerted by the vapors of condensates and of blends. In making the tests a small steel container of about 2-liter capacity was fitted with a pressure gage. A hole was bored in the bottom of the container for the introduction of the liquid. This hole could be securely closed with a small threaded steel plug. To determine the pressure exerted at different temperatures, the container was placed in a water bath heated by a gas burner. Pressure, temperature, and specific-gravity observations were made.

In figure 15, curve 1 shows the vapor pressures of a freshly drawn condensate having a specific gravity of 93° B. The vapor pressures ranged from 19 pounds per square inch at 55° F. (13° C.) to 48 pounds per square inch at 100° F. (38° C.).

After the test represented by curve 1 had been completed, the steel plug was removed from the container and the liquid allowed to volatilize until it had lost 10 per cent of its original volume. Then the plug was again inserted and the vapor pressures were again noted for different temperatures, as shown by curve 2. Curves 3, 4, and 5 show the vapor pressures at different temperatures after the original condensate had lost 20, 30, and 40 per cent of its original volume. It will be observed that the greatest drop in vapor pressure occurred after the first 10 per cent loss. This is due to the fact that the liquefied gases, propane and butane, were escaping in largest quantities during the first part of the exposure. There was not much difference in the vapor pressures after 30 and 40 per cent losses, as shown by curves 4 and 5.

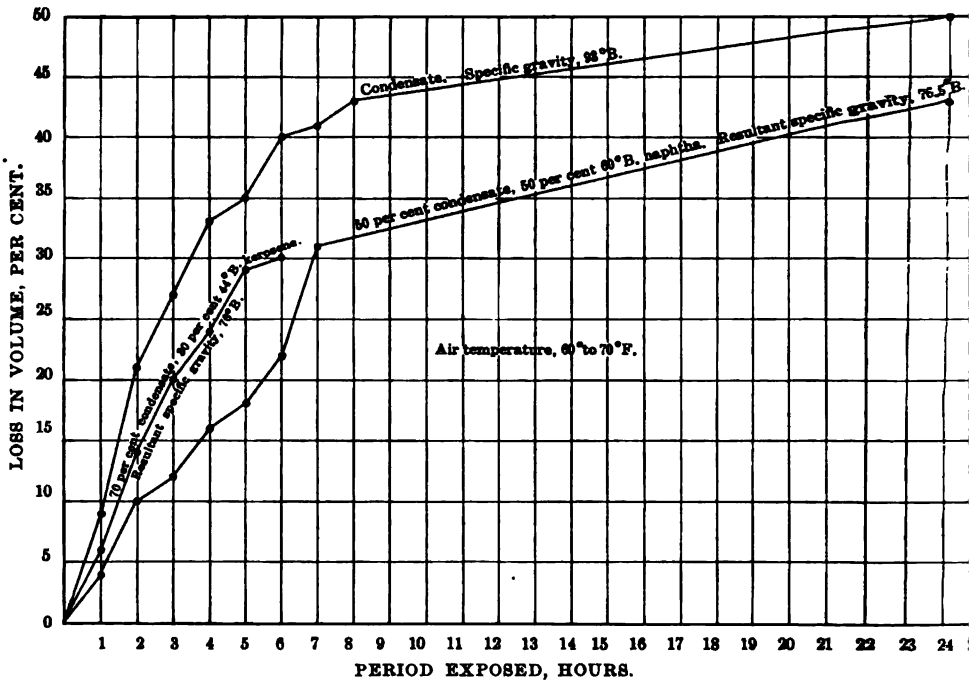
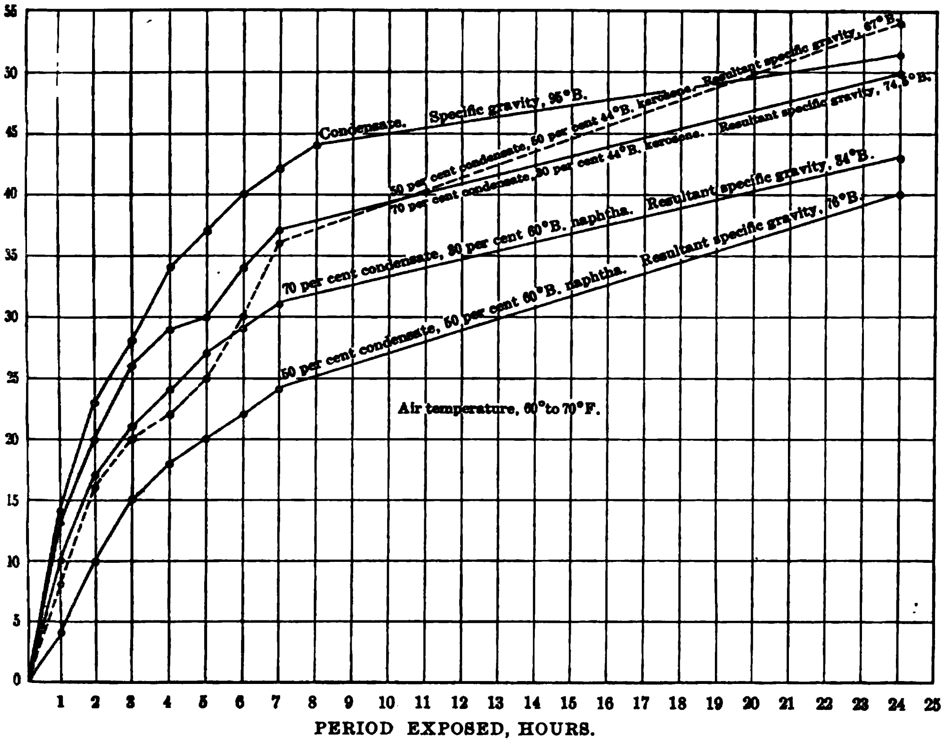


FIGURE 13.—Evaporation losses from a condensate with a specific gravity of 93° B., and from the same condensa mixed with kerosene and with naphtha. Sudden bend in lower curve at 7 hours due to accidental violent agitati of mixture, causing more rapid loss.

Figure 16 shows the vapor pressures of a condensate obtained at the same plant as that represented in figure 15, but at a different time. It will be observed that the condensate represented by curve 1, figure 16, and that represented by curve 1, figure 15, were of the same specific gravity, but produced appreciably different vapor pressures at the same temperatures. In other words, condensates of same specific gravity may produce quite different vapor pressures. A striking instance of such a variation can be noticed by comparing curve 3, figure 16, representing the vapor pressure of a condensate with a specific gravity of 78° B., with curve 5, figure 15, representing the vapor pressure of a condensate with a specific gravity of 88° B. The condensate with a specific gravity of 88° B. had a lower vapor pressure than the condensate with a specific gravity of 78° B. However, the condensate represented by curve 5, figure 15, had weathered long enough to lose 40 per cent of its original volume, and the condensate represented by curve 3, figure 16, was freshly drawn. From the former, liquefied gases and liquids of low boiling point had been largely removed, and in the latter there may have been enough of the liquefied gases to exert a pronounced vapor pressure, but not enough to greatly affect the specific gravity. After exposure to the atmosphere for an hour or even less, the condensate with a specific gravity



IGURE 14.—Evaporation losses from a condensate with a specific gravity of 95° B., and from the same condensate mixed with kerosene and with naphtha.

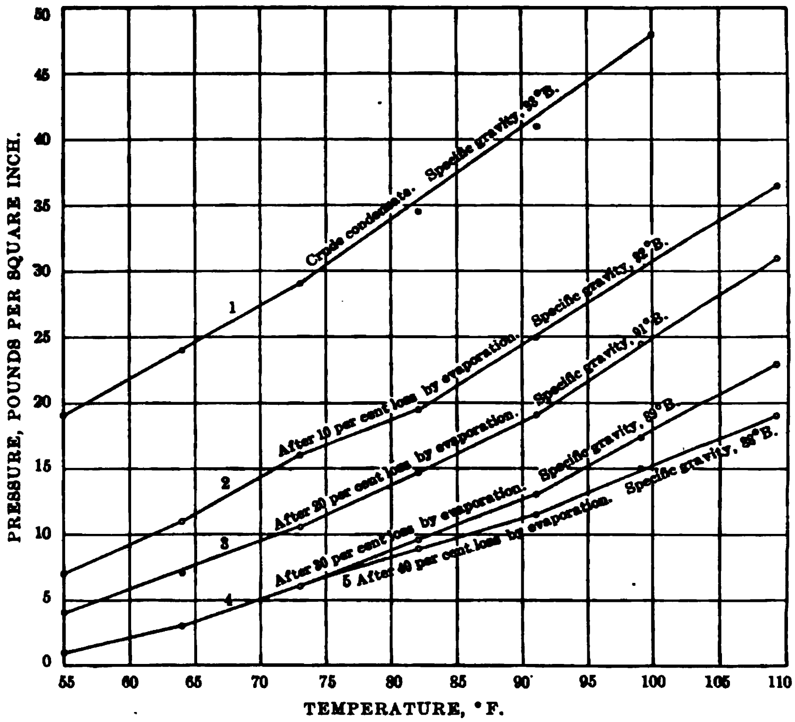


FIGURE 15.—Vapor-pressure curves of natural-gas condensate under different conditions.

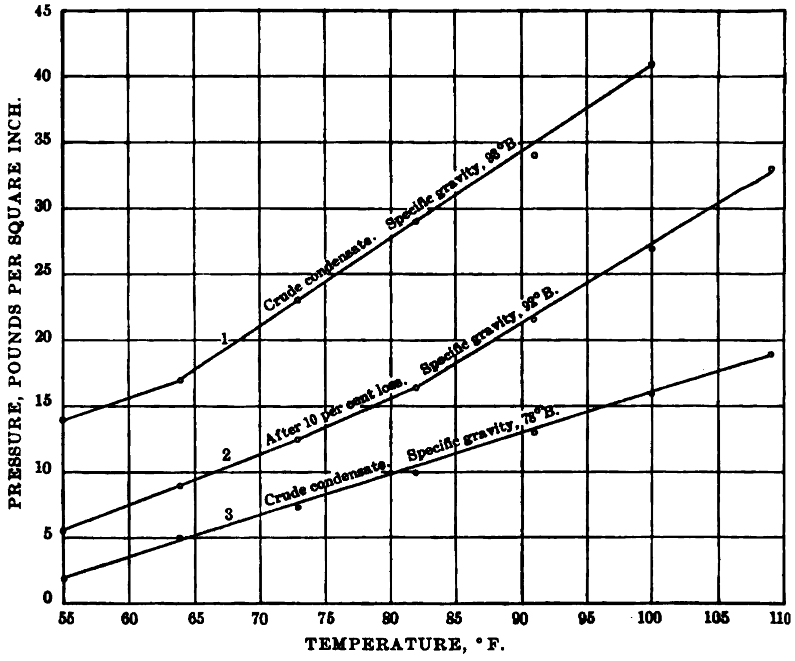


FIGURE 16.—Vapor-pressure curves of two condensates.

of 78° B. would have been greatly diminished in vapor pressure owing to the rapid evaporation of liquid gases, principally propane and butane.

In figure 17 are shown the vapor pressures of a freshly drawn condensate (curve 1), and of a blend prepared by mixing this condensate with refinery naphtha in equal proportions (curves 2 to 6). The naphtha had a specific gravity of 60° B. When the fresh condensate was mixed with the naphtha the vapor pressure (curve 2) was lowered between 6 and 14 pounds per square inch over a range of temperature from 55° to 110° F. (13° to 43° C.). Curves 3 to 6 show the vapor pressures at different temperatures after the condensate had lost 10, 20, 30, and 40 per cent of its original volume by evaporation. The condensate represented by curve 1 was the same as that represented by curve 1, figure 16. Comparison of curve 2, figure 17, with curve 3, figure 17, again brings out the fact that mixtures of the same specific gravity may have different vapor pressures at the same temperature. In this instance both condensates were used when freshly drawn. Curve 2, figure 17, represents the fresh condensate mixed with naphtha in equal proportions, producing a mixture having a specific gravity of

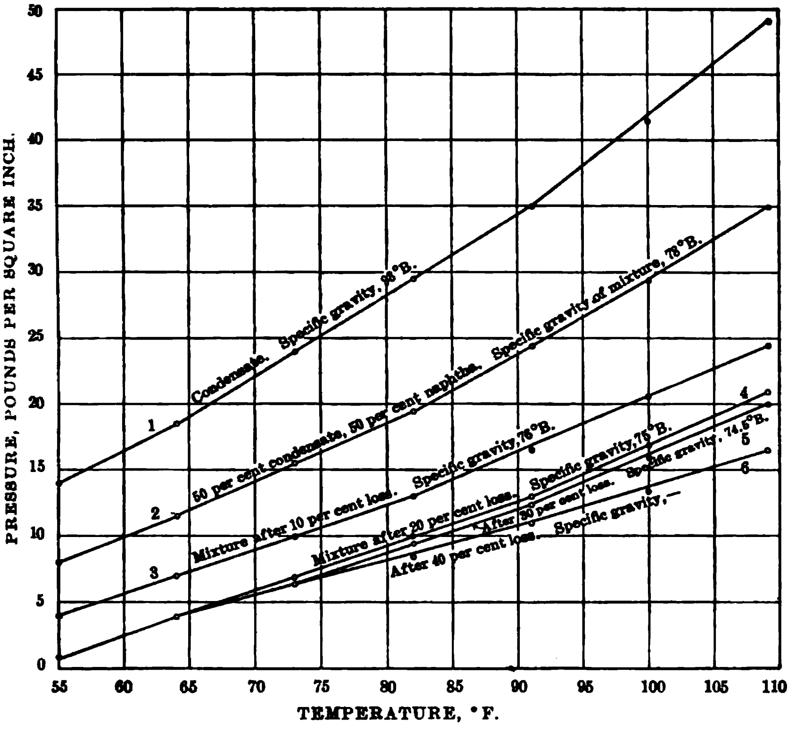


FIGURE 17.—Vapor-pressure curves of a freshly drawn condensate and of a blend of 50 per cent of the condensate and 50 per cent of refinery naphtha.

78° B. Curve 3, figure 16, represents freshly drawn condensate with a specific gravity of 78° B. The vapor pressure of the latter was lower than that of the former.

In figure 18 are shown the vapor pressures of different mixtures of a condensate with naphtha (specific gravity, 60° B.) and with kerosene (specific gravity, 44°B.). The condensate used in making the blends had a specific gravity of 93° B. It was the same condensate as that represented by curve 1, figure 17, and curve 1, figure 16. Curve 1 of figure 18 shows the vapor pressures at different temperatures when 70 per cent of freshly drawn condensate was mixed with 30 per cent of naphtha. Curve 3 shows the vapor pressures at different temperatures after the mixture represented by curve 1 had lost 10 per cent of its original volume by evaporation.

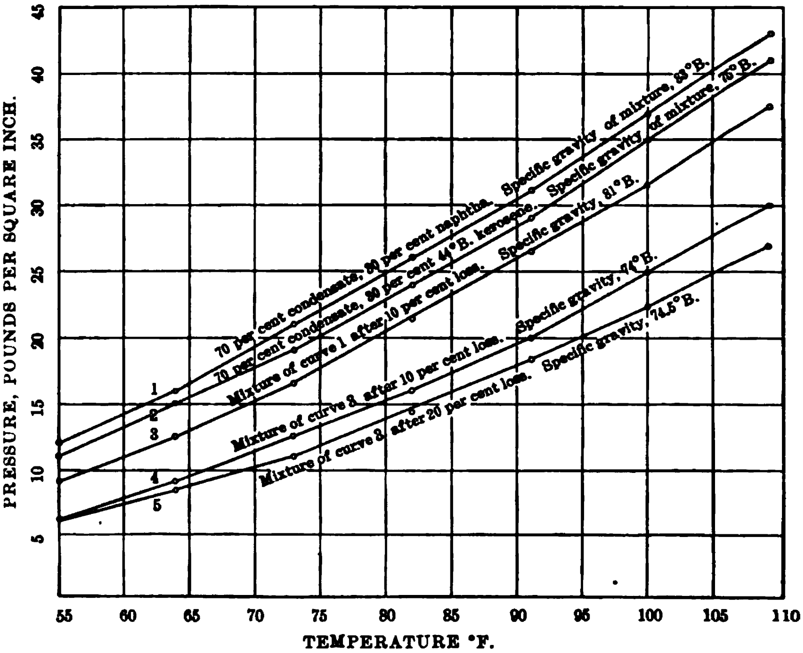


FIGURE 18.—Vapor pressures of different mixtures of a condensate with naphtha and with kerosene.

Curve 2 of figure 18 shows the vapor pressures at different temperatures when 70 per cent of the freshly drawn condensate was mixed with 30 per cent of kerosene. Curve 4 shows the vapor pressures at different temperatures when the mixture represented by curve 2 had lost 10 per cent of its original volume by evaporation. Curve 5 shows the vapor pressures at different temperatures after the mixture represented by curve 2 had lost 20 per cent of its volume by evaporation.

METHODS OF BLENDING.

Methods of mixing the natural-gas condensate and naphtha differ in detail in different sections of the country and even at some plants in the same section of the country. In some plants mixing is performed at the plant; that is, the naphtha is brought to the plant. The mixture is made and the blended material is hauled away in wagons or forced through pipe lines to the railroad.

The condensate from other plants is hauled in wagons, boats, or tank cars to central blending stations, and the mixture with the naphtha is made there.

One company in the Glenn pool district, Okla., has an elaborate system of blending. Naphtha is unloaded at the little town of Kiefer on the edge of the pool, where large storage tanks are provided for receiving it. The naphtha is then forced from the tanks through pipe lines to many different gasoline plants in the Glenn pool district. At each of these plants a mixing tank, the property of the company, is installed. The condensate from the storage tanks of the plant is forced into the mixing tank where it mixes with the naphtha. After the blend has become uniform the mixture is forced back through pipes to the railroad station at Kiefer, where it is received in tanks to await shipment to consuming centers.

In the region around Bradford, Pa., wagons partly loaded with naphtha are sent from a refinery. At each gasoline plant where this wagon stops it receives a quota of natural-gas condensate, which is mixed with the naphtha already in the wagon.

At a large blending station in Pittsburgh the natural-gas gasoline is received by freight in steel drums. The drums are emptied while still in the car, their contents being forced through a pipe to a container that holds the proper quantity of naphtha. A great deal of the natural-gas condensate is blended at Parkersburg, W. Va., in this manner. Much of the condensate is shipped by boat on the Ohio River to Parkersburg.

One operator in Oklahoma forces the condensate through a pipe line about 12 miles long to a railroad siding, where the mixing with the naphtha is accomplished.

At one plant the condensate is not blended, but shipped to a point of consumption, where it is used for the purpose of making gasoline-air gas.

At a plant at Alluwee, Okla., the gasoline is forced into the same pipe lines that convey oil. At the refinery the mixture of oil and gasoline is subjected to distillation, and the gasoline is reclaimed along with that originally in the oil. The refinery is at Coffeyville, Kans.

It follows from what has already been said that the blending of natural-gas condensates with refinery naphthas results in lower vapor pressures and slower rates of evaporation of the condensate; hence, in order to conserve the condensate as much as possible, it should be blended with naphtha as soon as practicable after it has been made.

SUMMARY.

Below is presented a brief summary of some of the more important details discussed herein.

GROWTH OF INDUSTRY.

The making of gasoline from natural gas increased from a production of a few thousand gallons in 1904 to about 24,000,000 gallons in 1913. Not until 1909 did the industry assume commercial importance, having its commercial inception in Pennsylvania, around Tidioute, Titusville, and Warren.

According to the United States Geological Survey the increase in production of gasoline for the year 1912 over 1911 was 63 per cent. The rate of increase for the year 1913 over 1912 was 100 per cent. It is reasonable to expect a greater increase for the year 1914. The gas used represents that which previous to the installation of plants for the production of gasoline was principally wasted.

CONSTITUENTS OF NATURAL GAS.

Natural gases are mixtures in which the hydrocarbons of the paraffin series predominate. Small quantities of nitrogen, carbon dioxide, and water vapor are also present. In some gases, however, the percentages of nitrogen and carbon dioxide are large. One analysis is shown in which nitrogen comprised 98.5 per cent of the total, and another in which the carbon dioxide equaled about 30 per cent of the total.

The exact proportions of constituents in natural gases can not be determined by ordinary methods of analysis, although the total quantity of paraffin hydrocarbons can be thus obtained and the heating value and specific gravity determined. Natural gas may be separated into its constituents by liquefying it by means of liquid air and separating the constituents of the liquified gas by fractional distillation. By this means the authors showed that the natural gas used in Pittsburgh contained 84.7 per cent methane, and that an extremely "wet" gas from which gasoline is condensed commercially contained only 36.8 per cent methane.

The paraffin hydrocarbons that principally concern the gasoline producer are methane, ethane, propane, and the butanes, pentanes, hexanes, and heptanes. The first four are gases at ordinary temperatures, the last three liquids. The gases after contact with the oil in the earth bring with them the vapors of the liquid hydrocarbons. The vapors are carried along with the permanent gases in the same manner that water vapor exists with air. After treatment in the gasoline plant, where the capacity of the gases to carry the vapors is much lessened, the vapors are deposited.

FACTORS AFFECTING YIELD OF GASOLINE FROM NATURAL GAS.

The quantity of gasoline vapors in any particular gas mixture is dependent upon the character of the oil in the sand, the temperature and pressure existing in the sands, the porosity or closeness of the strata, the intimateness of contact between gas and oil, and other less important factors. The pentanes, hexanes, and heptanes are the only constituents of crude oil that, at earth temperatures, have vapor pressures of such magnitude that they are distilled in quantity from the crude oil; hence, they are the chief liquid constituents of natural-gas gasoline.

In wells yielding gas suitable for gasoline condensation, the three gases, methane, ethane, and propane, invariably occur in the gaseous condition, and butane also is usually present in the gaseous condition.

METHODS OF TESTING FOR GASOLINE YIELD.

By itself the ordinary eudiometric analysis is of little use for testing a sample of natural gas in order to determine its suitability for gasoline production. Laboratory methods in principal use have to do with solubility and specific-gravity tests. The Bureau of Mines has used alcohol and claroline oil; 100 c.c. of the gas is shaken with 35 c.c. of the oil or with 50 c.c. of the alcohol until absorption ceases. For the determination of specific gravity the authors have both weighed the gas and used Bunsen's effusion method. The authors have found that natural gases at present used for gasoline production have a specific gravity of 0.80 or higher, and are soluble to the extent of 30 per cent or more in the solvents used. Laboratory tests serve best as preliminary indications previous to tests of the gas at the well by means of an experimental compressing plant.

USE OF PITOT TUBE AND GAS-ANALYSIS APPARATUS.

The Pitot tube as ordinarily used for measuring the flow of gases, that is, where the static pressure is not obtained, may give results that are 8 per cent in error, even though the tube is correctly used. When the static pressure is obtained and all readings are taken with a sufficient degree of refinement, they may vary only 1 per cent more or less from the correct results. The amount of casing-head gas that flows from a casing head may vary from little or nothing up to 500,000 or more cubic feet of gas. Wells should be allowed to vent from 3 to 24 hours before measurements of the flow are made.

A simple gas-analysis determination will show an operator whether air is leaking into his gas mains. Some gases that are used for condensing gasoline contain 40 per cent or more of air due to leakage.

LIFE OF WELLS AS REGARDS GASOLINE PRODUCTION.

Regarding the life of wells as to flow of gas for gasoline condensation, it can be stated that wells from which gas has been escaping freely for several years will be long enough lived to insure a return of the initial investment with profit, that is, if the gas contains the necessary quantity of gasoline vapors.

DATA REGARDING COMPRESSION.

The condensation of gasoline from natural gas is a physical process. The process in principal use at the present time consists essentially in compressing the gas to pressures up to 300 pounds and cooling it with water of ordinary temperature. Cooling the gas by means of a refrigerant without compression, or using a refrigerant other than water in conjunction with compressors, are processes that are coming into use.

The pressure best suited for the condensation of gasoline from natural gas depends upon the partial pressures of the gases and vapors present in the mixture. The partial pressures are difficult to determine. Hence the best that one can do in plant operation is to experiment until the most suitable pressures are found.

Single-stage and two-stage compressors are generally used in gasoline-plant operations. Single-stage compressors are generally used where pressures of 110 pounds per square inch are not exceeded.

In most two-stage plants little condensate is obtained after the first compression.

Several changes occur in the gas when it is treated in a gasoline plant for the condensation of gasoline. One has to do with the condensation of vapor, another with the liquefaction of gas, and a third with the solubility of gases in the liquids produced.

The condensate as it is received in the accumulator tanks consists principally of the liquids pentane and hexane and the liquefied gas butane. Some heptane and liquid propane may also be present.

For a particular natural gas there is a certain pressure best suited to produce the most salable gasoline. Increasing the pressure may result in producing more condensate in the accumulator tanks, but the additional yield may be so volatile as to quickly escape after exposure to air.

The quantity of gas that dissolves in the condensate in the accumulator tank is so small as to be insignificant.

At least one plant in the United States using a refrigerative method with low pressures is in successful operation.

COST DATA.

Exclusive of foundations and housing for machinery, pipe lines to wells, railroad sidings, storage tanks, etc., the compression and condensing equipment for gasoline plants costs from about $2,800 for a plant for handling 120,000 cubic feet of gas up to $7,800 for a plant for handling 600,000 to 700,000 cubic feet of gas. Two plants that produced 490,000 gallons of gasoline in 1913 cost $40,000 to complete. The owners realized 55 per cent on their investment the first year.

About 35 cubic feet of gas disappears at some plants for each gallon of condensate produced from 1,000 cubic feet of gas. At other plants, as much as 500 cubic feet of gas may disappear.

HEATING VALUES AND EXPLOSIVE LIMITS OF NATURAL GASES.

The heating value of the natural gas used for the condensation of gasoline from natural gas may be as high as 2,500 British thermal units at 0° C. and 760 mm. pressure. None of the residual gases that the authors tested had a heating value lower than 1,000 British thermal units. At one plant the residual gas had a heating value of almost 2,300 British thermal units.

The explosive limits of the natural gases used for the condensation of gasoline from natural gas are low and narrow. These limits are approximately, for the low limit, 3.5 per cent gas, and for the high limit, 9.5 per cent gas. Special precautions must be taken to avoid explosions.

EVAPORATION LOSSES.

Evaporation losses that resulted when natural-gas condensates of different specific gravities were exposed to the atmosphere in certain forms of containers ranged at one plant from 4.5 per cent to 24 per cent at the end of the first hour, from 8.5 to 33 per cent at the end of the second hour, from 9.5 to 40 per cent at the end of the third hour, and about 54 per cent at the end of 18 and 24 hours.

At another plant the losses for condensate ranging from a specific gravity of 79° to 98° B. were 0 to 19 per cent for the first hour, 0 to 26 per cent for 2 hours, 1 to 34 per cent for 3 hours, 2 to 38 per cent for 4 hours, 3 to 45 per cent for 6 hours, 4 to 48 per cent for 7 hours, 4 to 46 per cent for 8 hours, and 10 to 65 per cent for 24 hours.

A slower rate of evaporation occurs from a mixture of refinery naphtha and a condensate than when the condensate is allowed to evaporate separately. In some tests conducted by the authors, the saving at the end of the first hour was about 6 per cent in favor of the blends; at the end of the second hour, about 10 per cent; at the end of the third hour, about 11 per cent; at the end of the fourth hour, about 10 per cent; at the end of the fifth hour, about 12 per cent; at the end of the sixth hour, about 11 per cent; at the end of the seventh hour, about 8 per cent; and at the end of the twenty-fourth hour, about 14 per cent.

VAPOR PRESSURES.

Freshly drawn condensates with a specific gravity of 93° B. may have a vapor pressure of 14 to 48 pounds per square inch at temperatures of 55° to 100° F. (13° to 38° C.). Condensates with a specific gravity of 78° B. may have vapor pressures ranging from 3 to 19 pounds per square inch at temperatures of 55° to 109° F. (13° to 43° C.).

After a condensate with a specific gravity of 93° B. has lost 40 per cent of its volume by evaporation the vapor pressures may range from 1 pound to 19 pounds per square inch at temperatures ranging from 55° to 109° F. (13° to 43° C.).

When a freshly drawn condensate having a specific gravity of 93° B. is mixed with refinery naphtha with a specific gravity of 60° B. the vapor pressures may be 57 to 70 per cent of the vapor pressure of the condensate alone.

Condensates of the same specific gravity may have different vapor pressures

ACKNOWLEDGMENTS.

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APPENDIX.

PATENTS COVERING THE SEPARATION AND USE OF THE LIGHT PARAFFIN HYDROCARBONS IN NATURAL GAS.

In Technical Paper 10[a] of the Bureau of Mines there were published experiments relating to the use of the light paraffin hydrocarbons in natural gas. It was recommended that some of these constituents be used as a liquefied gas in the same manner that Pintsch, Blau, and other gases, transportable in containers under pressure, are used. At least one company developed the industry to the point of making gas installations. Some patents relating to this phase of the use of liquid products of natural gas are noted here.

U. S. patent 1031664, issued to F. P. Peterson July 2, 1912, discloses a process of condensing and separating different compounds in natural gas at different pressures and temperatures and collecting the condensate for each stage separately. The expanded residue of the gases is caused to flow countercurrent to the compressed gases and thereby cool them.

U. S. patent 1056845, issued to W. O. Snelling March 25, 1913, also discloses a process of separating some of the compounds from natural gas. A heated mixture of the gases is subjected under pressure to the condensing action of a series of condensers, each of which is maintained at a temperature just below the boiling point, at the high pressure to which the mixture is subjected, of the constituents condensed thereby.

U. S. patent 1094864, issued to F. P. Peterson April 28, 1914, claims a new composition of matter, consisting of a liquefied mixture of ethane, propane, and butane, produced from natural gas and substantially free from other hydrocarbons. Peterson claims as an advantageous process for obtaining the above mixture, the process patented by him on July 2, 1912 (U. S. patent 1031664).

TRAP FOR SAVING GAS FROM GUSHERS.

An elaborate trap for saving the gas from large gushers and separating the gasoline from the gas is described in the California Derrick,[b] the statement being made that this new method of conserving the gasoline in the escaping gas has taken the place of the gas compressor on certain properties in California. The principle underlying the method is the natural separation of associated oil and gas in a long chamber—a 10-inch pipe 800 feet long—which is tapped at short intervals by "risers" (separately controllable) into which the gas flows while the oil and sand under the pressure from the well, flow through the 10-inch pipe. When the oil and sand reach the end of the pipe, they are drawn into a receiving tank where the sand settles. As the gas is tapped at various points on the upper surface of the pipe, a rush of gas is prevented and the pressure is uniformly maintained over the entire surface of the oil as it passes along the pipe. When the gas leaves the oil it is said to contain only such of the light products as are proportionate to the temperature and pressure. The trap was devised by Dr. Eric A. Starke, who patented it October 8, 1912.

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[a] Allen, I. C., and Burrell, G. A.: Liquefied products from natural gas, their properties and uses: Technical Paper 10, Bureau of Mines, 1912, 23 pp.

[b] Conservation of gas and oil in California. California Derrick, vol. 7, Sept. 10, 1914.

PUBLICATIONS ON PETROLEUM TECHNOLOGY.

A limited supply of the following publications of the Bureau of Mines is temporarily available for free distribution. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

BULLETIN 19. Physical and chemical properties of the petroleums of the San Joaquin Valley, Cal., by I. C. Allen and W. A. Jacobs, with a chapter on analyses of natural gas from the southern California oil fields, by G. A. Burrell. 1911. 60 pp., 2 pls., 10 figs.

TECHNICAL PAPER 3. Specifications for the purchase of fuel oil for the Government, with directions for sampling oil and natural gas, by I. C. Allen. 1911. 13 pp.

TECHNICAL PAPER 10. Liquefied products from natural gas; their properties and uses, by I. C. Allen and G. A. Burrell. 1912. 23 pp.

TECHNICAL PAPER 25. Methods for the determination of water in petroleum and its products, by I. C. Allen and W. A. Jacobs. 1912. 13 pp., 2 figs.

TECHNICAL PAPER 32. The cementing process of excluding water from oil wells as practiced in California, by Ralph Arnold and V. R. Garfias. 1913. 12 pp., 1 fig.

TECHNICAL PAPER 37. Heavy oil as fuel for internal-combustion engines, by I. C. Allen. 1913. 36 pp.

TECHNICAL PAPER 38. Wastes in the production and utilization of natural gas and means for their prevention, by Ralph Arnold and F. G. Clapp. 1913. 29 pp.

TECHNICAL PAPER 42. The prevention of waste of oil and gas from flowing wells in California, with a discussion of special methods used by J. A. Pollard, by Ralph Arnold and V. R. Garfias. 1913. 15 pp., 2 pls., 4 figs.

TECHNICAL PAPER 45. Waste of oil and gas in the Mid-Continent fields, by R. S. Blatchley. 1914. 54 pp., 2 pls., 15 figs.

TECHNICAL PAPER 49. The flash point of oils; methods and apparatus for its determination, by I. C. Allen and A. S. Crossfield. 1913. 31 pp., 2 figs.

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TECHNICAL PAPER 57. A preliminary report on the utilization of oil and natural gas in Wyoming, by W. R. Calvert, with a discussion of the suitability of natural gas for making gasoline, by G. A. Burrell. 1913. 23 pp.

TECHNICAL PAPER 66. Mud-laden fluid applied to well drilling, by J. A. Pollard and A. G. Heggem. 1914. 21 pp., 12 figs.

TECHNICAL PAPER 68. Drilling wells in Oklahoma by the mud-laden fluid method, by A. G. Heggem and J. A. Pollard. 1914. 27 pp., 5 figs.

TECHNICAL PAPER 70. Methods of oil recovery as practiced in California, by Ralph Arnold and V. R. Garfias. 1914. 57 pp., 7 figs.

TECHNICAL PAPER 72. Problems of the petroleum industry; results of conferences at Pittsburgh, Pa., August 1 and September 10, 1913, by I. C. Allen. 1914. 20 pp.

TECHNICAL PAPER 74. Physical and chemical properties of the petroleums of California, by I. C. Allen, W. A. Jacobs, A. S. Crossfield, and R. R. Matthews. 1914. 38 pp., 1 fig.

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Bulletin 89

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
BUREAU OF MINES
VAN. H. MANNING, DIRECTOR

ECONOMIC METHODS OF UTILIZING WESTERN LIGNITES

BY

E. J. BABCOCK

WASHINGTON
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ECONOMIC METHODS OF UTILIZING WESTERN LIGNITES.

By E. J. Babcock.

INTRODUCTION.

EXTENT OF LIGNITE DEPOSITS.

The existence of vast deposits of lignite in the West Central and Western States is well known, although the extent and importance of the deposits have not been appreciated, nor has there been an adequate economic utilization of the deposits.

The work of the Bureau of Mines, the United States Geological Survey, and the State geological surveys is disclosing an increasingly large area, underlaid with this kind of coal. Among the States having the largest workable deposits may be mentioned North Dakota, Montana, Wyoming, Colorado, and Texas, and in several other Western States lignite occurs in smaller areas. In North Dakota alone it is estimated that the deposits cover approximately 32,000 square miles, many of them being 10 to 15 feet thick and capable of producing in all several hundred billions of tons of lignite.

When one stops to consider what these figures mean as to the immensity of these deposits in the West, it is not strange that people are seeking to ascertain better means for deriving larger benefits from the proper utilization of those great deposits. Consequently, any proposed methods of utilization that are promising are well worthy of careful consideration.

PURPOSE AND SCOPE OF THE INVESTIGATIONS.

The Bureau of Mines has been investigating more efficient methods of utilizing fuels, the pertinent reports issued by the bureau being given in the list at the end of this volume. In the State of North Dakota there has been begun at the college of mining engineering of the University of North Dakota, at Grand Forks, and at the mining substation, at Hebron, extended work on a variety of new and practical methods of using lignite. In this work special attention has been paid to the production of gas and its utility and economy for heating, lighting, and power purposes and the manufacture of briquets. In addition, many other improvements in methods of burning and utilizing lignite have been attempted. As the Federal Government controls great tracts of land underlain with lignite, it has a direct interest in the utilization of this fuel, and the Bureau of Mines, in its investigations of fuels belonging to or for the use of the Government, has cooperated in the study of lignite.

The purpose of this bulletin is to present a summary of the results thus far obtained in the work done at the college of mining engineering and at the mining substation of North Dakota, and to indicate the prospects that the results hold out for the future development of the lignite fields of the West.

What has been accomplished in this experimental work leads to the belief that great improvements can be made in the methods of utilizing lignite and in the manufacture of cheap gas for power and other purposes, and that the making of high-grade fuel briquets can be put on a commercially satisfactory basis. The result will be that not only will lignite be much more serviceable and much more generally used, but an immense quantity of slack and coal that would otherwise be wasted will be saved.

Furthermore, by the process described in this bulletin, large quantities of gas, especially valuable for power purposes, may be obtained at a low cost, as the work thus far carried on indicates that this gas can be used successfully with an internal-combustion engine for the production of electricity so as greatly to reduce the cost of power production and thus make possible a wide utilization of cheap electricity for industrial purposes.

CHARACTERISTICS OF WESTERN LIGNITES.

In order better to understand why these lignite deposits have not been developed more rapidly and to see what changes are needed to increase their value and usefulness, it is necessary at the start to consider certain general characteristics of lignite. Inasmuch as the work herein reported has been largely done at the school of mines and the mining substation of the University of North Dakota, most of the references and data here given are based on North Dakota lignite; however, the results of tests of lignites from several other States are presented.

Western lignites, from different localities, though in general similar, differ somewhat in both physical and chemical properties. Not only in different districts, but also in different mines, the composition varies considerably, especially in ash content, a matter of much importance in connection with the utilization of lignites. If the ash content of a lignite to be used in the production of gas is high, the ash content in the residue will be considerably increased through concentration in carbonization, and hence the residue will be less valuable for use in making briquets.

PHYSICAL CHARACTERISTICS.

Most Western lignites are brownish-black, few having much luster, but some samples approach, in appearance only, the duller varieties of cannel coal. In some districts, however, the seams are harder and more compact, and have a dark color and considerable luster. There is some difference in the character of the seams at different levels. Many of the upper deposits are too thin to be operated, and some are strikingly lignitic in color and structure, whereas the lower seams may be darker, more compact, and less friable. In many localities such seams might quite properly be classified as subbituminous coal, particularly some of the deposits in Montana, Wyoming, and Colorado. In many of these deposits, as in some of the North Dakota deposits, the lignite shows little or none of the woody structure characteristic of a true lignite, but in many of the Western deposits it is dark, semilustrous, and lacking in the physical characteristics of lignite, although the lignite character is revealed in chemical tests, in burning, usually in slacking, and in the character of the residue, the gas, and other by-products.

VARIATION IN COMPOSITION OF DIFFERENT COALS.

From a chemist's point of view it may be said that in a general way the quality of a coal depends largely on the proportions of fixed carbon, volatile matter, and ash. Coal consists chiefly of organic matter, but contains varying proportions of inorganic or incombustible material—substances that were originally in the framework and sap of the plant, or were carried in as foreign material during the period of deposition. When coal is burned the organic matter is consumed and passes away as gas, but the inorganic part is left behind as ash. The relative proportion of the ash determines to a considerable degree the purity and the value of the coal. A coal that contains less than 5 per cent of ash may be considered as rather free from foreign impurities. Some bituminous and hard coals used contain 15 to 20 per cent of ash. If more than 10 per cent is found the coal may be considered impure; that is, mixed with foreign matter, generally in the form of clay which has worked its way into the deposit either during the period of deposition or after the accumulation of the coal.

SULPHUR CONTENT OBJECTIONABLE.

One of the most objectionable impurities in coals is sulphur, which is undesirable in almost all uses to which coal may be put. It tends to lessen the heating qualities of a coal and gives off obnoxious gases that corrode furnace grates and metallic surfaces in the flues. Most Western lignites, however, do not contain a large percentage of sulphur.

USUAL PROPORTIONS OF VOLATILE MATTER AND FIXED CARBON.

The combustible matter of coal is partly fixed (not easily driven off as gas), known as fixed carbon, and partly volatile, easily converted into gas. The fixed carbon corresponds to charcoal in wood, and in certain grades of bituminous coals is known as coke.

Most anthracite coal contains 80 to 90 per cent fixed carbon, is dense and hard, and has characteristic physical properties. Most semianthracite coal contains 70 to 80 per cent fixed carbon, whereas most bituminous coal contains 50 to 70 per cent fixed carbon. Many of the bituminous coals, rich in volatile matter, when burned in a retort produce a coke well adapted to manufacturing and metallurgical purposes. Most Western lignites do not contain more than 40 to 55 per cent of fixed carbon, and when burned in a retort the fixed carbon does not coke, but remains as somewhat shrunken and broken lumps of residue which, although rather high in calorific value, are of little value until briquetted into proper size and strength for use in stoves and furnaces, or under boilers.

AVERAGE COMPOSITIONS OF DIFFERENT WESTERN LIGNITES.

The results of many hundreds of analyses of lignite samples made under the direction of the writer indicate that the average composition of Western lignites when dry is about as follows: Fixed carbon, 51 per cent; volatile matter, 39 per cent; ash, 10 per cent. The moisture in the lignites as mined is 15 to 35 or even 40 per cent.

The average composition of North Dakota dry lignite is probably about as follows: Fixed carbon, 49 per cent; volatile matter, 43 per cent; ash, 8 per cent. The moisture in the lignite as mined is 25 to 35 per cent.

In a general way it may be said that 1 ton of Western lignite when dry will equal 0.4 to 0.7 ton of Eastern bituminous coal, the exact comparative values depending on the particular grades of lignite and of bituminous coal used for comparison.

EFFECT OF MOISTURE CONTENT OF LIGNITE.

Lignite, especially in large blocks as mined, breaks up easily when exposed to air. Such disintegration is no doubt due in large part to the rapid evaporation of water, which constitutes 20 to 35 per cent of most lignite as taken from the mines. The larger part of this moisture escapes rapidly and causes thereby checking and splitting of the lumps, eventually converting piles of lignite lumps into slack. This slacking is one of the greatest difficulties to be overcome in the commercial handling and utilizing of lignites and seems to be a general characteristic of the deposits throughout the West.

The cost of shipping coal containing so much moisture is high, and the moisture content causes a corresponding reduction in the efficiency of the fuel. It is, therefore, inportant that the moisture be removed before shipment. However the tendency of the coal to form slack when burned, even after the moisture has been removed, presents another difficult problem. As a result, the utilization of lignite has been confined to comparatively narrow regions near the deposits. The utilization of this coal would be enormously stimulated could it be satisfactorily and economically converted or concentrated into fuel free from moisture and of a size and strength adapted to general commercial uses; hence the development of some economical means of briquetting lignite is highly important.

THE PREPARATION OF LIGNITE FOR BURNING.

Lack of familiarity with the character of lignite and lack of knowledge of the best methods of burning it make many people unwilling to use this kind of coal. However, the use is gradually being extended as from time to time more perfect methods of burning appear.

MOISTURE CONTENT SHOULD BE REDUCED.

Improved methods of preparing lignite for the market have been developed and will no doubt sooner or later be adopted by mine operators. A universal mistake is made in burning lignite coal with too large a percentage of moisture. Most lignite when taken from the mine contains more than 25 per cent of moisture, which seriously interferes with the heating power of the fuel. If the lignite could be seasoned and broken into lümps of uniform small size before it is put on the market, the popularity and real value of the lignite would be greatly increased. Lignite that has been broken before drying does not slack as badly as when left to dry in large lumps. When the large masses dry the evaporation takes place from the surface and causes the masses to split into thin, small pieces. If the large lumps are first broken to about 3-inch size and then allowed to dry, the loss in slack is much reduced.

TESTS OF EFFECT OF ATMOSPHERIC DRYING.

In order to determine the possibility of removing any considerable proportion of the moisture from freshly mined lignite by exposure to atmospheric drying, and to determine also whether such atmospheric drying would cause any material loss of fuel value, a series of careful tests was performed. The tests were made with a pile of typical lignite taken directly from the mines and exposed to the effect of the air and weather for three weeks during the month of August. The coal was analyzed at the beginning and during the tests to determine the percentage of moisture, volatile matter, fixed carbon, and ash, and the heating value.

The determinations were made every third or fourth day. The records at the start and at the end of 14 days were as follows:

Results of exposure of lignite to weather.

Condition of lignite.	Moisture.	Volatile matter.	Fixed carbon.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
As mined	33.5	25.5	35	6
After 14-day exposure	12.52	34.83	46.05	7.6

In these tests there was a gradual decrease in the moisture until about 12.5 per cent was reached, at the end of about 14 days. Subsequently there was practically no further reduction in the moisture content. It would thus appear that in summer weather an exposure of freshly mined lignite for two or three weeks would materially reduce the percentage of moisture. There seems to be slight chemical change, and the heating value, as shown by numerous calorimeter determinations, is increased in proportion to the moisture removed. During this exposure the usual slacking occurred, but seemed to be much less when the coal while fresh from the mine was broken into small lumps.

LABORATORY TESTS OF EVAPORATIVE AND HEATING QUALITIES OF LIGNITE AND OF BITUMINOUS COAL.

In order to determine more perfectly by actual burning tests the effect of different kinds of treatment on the heating and evaporative power of North Dakota lignite carefully conducted laboratory stove tests were made. Average samples weighing several hundred pounds were taken from a number of mines, and the effect of differences in moisture content and in size of lump was studied. The results were compared with the results of similar tests of a high grade of bituminous coal, namely, a selected lot of screened Youghiogheny coal. The tests were made under exactly the same conditions and therefore permitted a close comparison with the sample of Youghiogheny taken as a standard. The idea of this test was not to determine the absolute theoretical heating power, but rather to determine by actual combustion in an especially arranged stove, in which conditions could be perfectly regulated, the heating and evaporative power of the lignite compared with the Youghiogheny standard. So far as the writer has been able to ascertain, no other such series of comparative stove tests of our lignites, combining the practical and scientific, has been made. The series mentioned furnished much and valuable information. There can be little doubt that the data will show nearly the relative heating value of the lignite coal as it is actually burned in the ordinary stove.

EQUIPMENT USED IN THE TESTS.

In order to carry on the tests in the most satisfactory manner, a special design of stove was procured. The stove was simple in construction and presented a large evaporative surface over which the reservoir for water-evaporation tests could be readily arranged. A sliding jacket or inclosure to prevent any modifying effects from the atmosphere of the room was provided.

The stove was set up in a small basement room. The tests were made in an inside room surrounded on all but one side by other rooms, a closely uniform normal or starting temperature being thus insured. The testing stove was connected with a chimney having a good draft, there being about 12 feet of pipe between the stove and the flue. The pipe was provided with two dampers to control the flow of air, and with a movable cap arranged for the introduction of a thermometer to determine the temperature of the flue gases and having provision for sampling the gases for analysis. Before each test the draft or flow of air through the stove and the temperature conditions where carefully regulated by means of an anemometer and thermometers arranged so as to give conditions that could be maintained practically the same for all the tests. The windows and the doors were kept closed during the tests. The temperature was taken at the start of each test by means of thermometers placed in different parts of the room. The temperature of the air in the dome above the water reservoir was taken as well as the temperature of the flue gases. Careful records of the temperature and of the weight of the water were kept.

MANNER OF CONDUCTING THE TESTS.

The fire was kindled with the same kind of material and the same quantity and in the same manner for every test. The same quantity of coal was weighed out each time. After a test had been started records were taken every 15 minutes while the fire lasted. The record showed the rise of temperature of the air of the room, the rise of the temperature of the air coming from the dome in which the water reservoir was placed, and the temperature of the flue gases.

After the first fire was out and the stove was cold, the water remaining was weighed and the total evaporation determined. The ashes were removed, weighed, and their percentage calculated. The ashes were then analyzed to determine the proportion of unconsumed combustible that they contained. The total number of degrees that the air of the room had been raised was then determined, and the total water evaporation from the reservoir was also determined, and from the results the relative heating and evaporative power of each sample of lignite was determined and compared with similar values for the standard bituminous coal used.

Some of the lignite was burned after having been broken to a size to pass a 2½-inch ring, being, therefore, about egg size. One set of samples from each mine was tested while containing the moisture remaining after shipment. Some tests were made of large lumps of lignite 6 to 10 inches in diameter. Other tests were made of egg-size lumps of lignite from which the moisture had been largely driven off. Before each lot of coal was placed in the stove average samples were taken and analyses made, to show the moisture, volatile matter, fixed carbon, and ash. The theoretical fuel value of each sample of lignite burned was calculated and compared with a similar estimate from the analysis of bituminous coal used as a standard. After the actual heating power based on the increase of air or room temperature and the amount of water evaporated had been ascertained, the theoretical and actual heating values of each sample of lignite were compared with similar values for the bituminous coal. An average of 16 of these stove tests of egg-sized lignite, its moisture content being the same as in the lignite as mined and marketed, showed about 50.6 per cent of the heating and evaporative value of the standard bituminous coal in a corresponding stove test. The average comparative heating and evaporative values of the egg-size dried lignite in the stove tests showed 65 to 75 per cent of the values obtained with the standard soft coal. Similar averages from the tests of the lignite burned in large lumps showed by the stove test about 40 per cent of the values of the standard bituminous coal subjected to the same tests.

RESULTS OF THE TESTS.

From these tests it was found that the theoretical values and the values indicated in the stove tests are fairly concordant. The highest heating power was shown by the dry coal and the lowest heating power was shown by the damp lignite when burned in large lumps. These facts are significant, as they show at once that there is considerable loss as well as great inconvenience in burning lignite in large lumps. The writer has long been convinced that lignite that is to be used in stoves should be broken at the mine to a comparatively uniform size, and it would seem that lumps of about 3 inches in diameter are about right for most purposes. Coal of this size is much more easily handled, and would therefore be more acceptable to the housewife for cooking and other domestic use. There is a great saving to the consumer in the use of dry lignite. Furthermore the coal burns so much more satisfactorily that it is better liked by the user, and as those not accustomed to the use of lignite coal always have some prejudice to overcome, the introduction of lignite would be greatly helped if it were dry and reduced to uniform and moderate size lumps. Such a change would be of service to the producers in popularizing their coal.

TABULATED DATA.

In order to show the system adopted in the comparative tests described, a part of the records is presented. Presentation of the full data from all of the tests does not seem warranted, but the essential results of the heating and evaporative tests of each coal and of the standard bituminous coal are presented in the following table, which also shows the composition of the coal as determined by chemical analyses:

Results of comparative heating and evaporative tests of lignite and bituminous coal.

Coal sample No.	Condition of coal.	Results of chemical analyses.				Results from burning fuel in direct-draft stove of special type.			
		Moisture in undried coal.	Proportions of constituents in dried coal.			Proportion of ash in air-dried coal.	Proportion of combustible remaining in ash.	Evaporative efficiency.	Heating efficiency.
			Volatile matter.	Fixed carbon.	Ash.				
		Per cent.	*Per cent.*	*Per ct.*	*Per ct.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	Large lumps, moist.	32.5	38.7	54.7	6.6	7.7		36	53
3	do.	32.0	38.1	54.2	7.7	17.8		31	
1	Egg size, moist.	32.5	38.7	54.7	6.6	7.7	1.4	46	68
4	do.	31.4	41.1	50.8	8.1		.9		60
3	do.	32.0	38.1	54.2	7.7	9.7	1.1	41	70
3	Egg size, dry		38.1	54.2	7.7	12.9	3.0	59	
5	do.		36.0	52.9	11.1		1.3	50	
6	do.		35.0	46.8	18.2			54	87
	(a)	1.4	31.0	61.0	8.0	12.7	6.4	100	100

[a] Youghiogheny high-grade bituminous coal.

COMMENTS ON THE RESULTS.

These practical burning tests give much reliable information concerning the relative value of lignite. Although the results did not equal those with the high-grade bituminous coal used, still the heating-efficiency percentage was sufficiently high to show a fuel of much value.

The large size of the lignite as shipped from the mine is a cause of real difficulty in burning it in ordinary stove and heating plants. Lumps weighing 25 to 50 pounds are common in the lignite as marketed. There is practically no sizing, and the coal used for small heating stoves is supplied in as large lumps as that used for steam boilers. At the mines the coal should be broken by machinery and graded to the proper size for use in stoves, heating plants, and steam boilers. Persons who use lignite dislike to stop to break it when they are ready to use it. Too large lumps do not give sufficient oxidizing surface but give too open a fire body. A fire box properly filled with egg-size lignite gives a compact body of fire and still presents a much larger fuel surface than if the lumps are larger. Even for steam boilers much of the lignite shipped is in too large lumps. The coal prepared in smaller lumps is not only easier to handle but seems to stand weathering much better. It also seemingly gives much better economy in burning, even under boilers, than it does in the large lumps as they come from the mine.

Proper combustion of lignite depends largely on the use of a size of coal that will give an abundant air surface. Moreover, the stove should have a good draft so arranged that the air can be directed up through the burning coal, but so that it can easily be controlled and closely shut down when a low heat is desired. The fire box should be kept well filled with coal. Many persons fail to get good results because they do not have sufficient lignite burning to keep up complete combustion of the gases and do not properly regulate the drafts.

For steaming purposes there is no doubt but that great improvement could be made in the methods generally employed. Many firemen in using lignite quite overlook its peculiar physical and chemical characteristics, such as its tendency to slack in the fire box, its lack of density, its noncoking qualities, its high percentage of moisture, and its richness in light volatile gases, and endeavor to operate their furnaces much the same as they would in the use of ordinary bituminous coal. The result is a high fuel combustion, extra labor costs, and loss of boiler efficiency. But when the peculiar characteristics of lignite are carefully considered in the selection of boiler grates and combustion chambers, and in the methods of burning, a great saving can be effected.

A matter of fundamental importance in any successful method of using lignite is the proper consumption of the large volume of light volatile gases present in all lignites. In the ordinary furnace and boiler construction the heating power of a considerable proportion of these gases is insufficiently utilized or they pass out with the flue gases almost entirely unburned.

EXAMPLES OF EFFECTIVE UTILIZATION OF LIGNITE IN POWER-PLANT BOILERS.

USE IN ELECTRIC POWER PLANT.

An especially successful utilization of lignite and lignite waste was made by Mr. C. L. Larsen, chief engineer of the Hughes Electric Co., of Bismarck, N. Dak. Referring to the fact that many people do not economically burn raw lignite, Mr. Larsen says:[a]

> They have not learned the real value of lignite or how to obtain the best results. Some people will order a few sample carloads and before the fireman has used half a

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[a] In a communication to the author.

car of it he will condemn the coal, and, if the engineer has had no previous experience in burning lignite he will soon fall in line with the fireman, with the result that the lignite is rejected entirely.

LARGE LUMPS UNDESIRABLE.

Speaking further of the use of lignite, Mr. Larsen writes as follows:

To break up lump coal to 1-inch and 2-inch sizes requires too much time and labor for the fireman; nevertheless this is the size that gives the best results when used with a forced draft—but not as strong a draft as some people think who complain of not enough draft.

PROPER DRAFT ESSENTIAL.

The ideal furnace condition is that of supplying just the amount of air necessary for complete combustion of the fuel; and the combustion should be nearly complete in the furnace, which can not be done with natural draft.

I am very much in favor of a balanced draft. It may not be understood what is meant by a balanced draft; I will therefore explain it a little more thoroughly. A balanced draft is obtained by regulating the air pressure under the grates and the dampers in the smokestack to such an extent that the pressure in the furnace is the same as that of the outside atmosphere.

It is not easy to maintain a balanced draft as the thickness of the fire and the demand for more steam interfere with the adjustment of the dampers in the stack and the blast gates; but it is advisable to keep the draft as nearly balanced as possible for the reason that the fire doors must be opened rather frequently in burning lignite, and if the draft is too strong more air than is needed is supplied, and the excess air reduces the temperature of the furnace. This is proved by analyzing and taking the temperature of flue gases resulting from the use of a balanced draft. We can maintain from 14 to 16 per cent CO_2 and a flue-gas temperature of 450° F. But by opening the damper enough to produce a 12/100-inch water draft and then opening one of the fire doors, in a short time, less than 10 seconds, the CO_2 will drop to 9 per cent; this indicates that about 20 per cent excess air is admitted to the furnace.

IMPORTANCE OF HIGH TEMPERATURE IN FURNACE.

The temperature of flue gases is deceiving when lignite is being burned, as it burns much like wood.

In the burning of coal decomposition always precedes combustion; hence the greater the amount of volatile combustible contained in the coal the greater the flame volume and the greater the length of flame, and the probability of greater loss by the low temperature of the flame. As our lignite contains much volatile matter and is low in fixed carbon, an excess of air will rush the flame through the boiler and produce a low temperature of flue gases, also a low temperature in the furnace.

In order to obtain a high efficiency from lignite, a high temperature is required in the furnace, and this can be obtained by a suitable grate. I have found that a flat saw-dust grate with ½-inch round holes gives the best results. Such grates contain only 15 per cent air space, but by having small openings we can maintain a higher air pressure in the ash pit, and the air passes through the small holes and through the bed of fuel at a greater velocity, which produces a high temperature in the furnace, and as the volume is small, the heat is not rushed through the boiler and up the smokestack, but is absorbed by the water in the boiler, and a low temperature in the smokestack is obtained.

Under such conditions with a good boiler and setting a pound of lignite containing 35 per cent moisture, 6 per cent ash, and 7,000 B. t. u. will evaporate nearly 5 pounds of water per pound of fuel.

BOILER SHOULD NOT BE CROWDED.

Such results can be obtained when a boiler is not crowded above its rated capacity, say 3 pounds of water per square foot of heating surface, as we can not force a boiler much over its rated capacity with lignite.

It is therefore advisable not to burn lignite under boilers that are forced as can be done with good Eastern coal. We can force a lignite fire to burn 60 pounds of coal per square foot of grate surface per hour, and not make any more steam than when burning 50 pounds per square foot of grate surface, owing to the excess air which has carried away 10 pounds of coal per square foot of grate surface, or 70,000 B. t. u. with a boiler having 30 square feet of grate.

It will be seen that Mr. Larsen's statements of the methods he employs so successfully are well borne out by the data presented in the foregoing pages with reference to the characteristics of lignite and the proper methods of burning this fuel.

EXPERIMENTS BY RANDALL AND KREISINGER.

Some excellent investigations as to the proper use of lignite as a fuel for power-plant boilers were carried on by Randall and Kreisinger.[a] The conclusions reached were that for best results the lignite should be reasonably low in moisture and that the combustion chamber should be sufficiently large and of such construction that the light liberated gases should be retained and heated to combustion temperature before being permitted to pass out as flue gas.

For the tests mentioned a modification of the so-called Dutch-oven type, a sort of semiproducer style, was adopted. The author's investigations lead him to believe that some modification of this general type of combustion-oven construction is best adapted for the direct use of lignite for steaming purposes. A few extracts[b] from the report of the investigators mentioned will give a more comprehensive idea of the construction and operation of this type of boiler furnace and the results achieved. The extracts follow:

CONSTRUCTION OF FURNACE USED.

The most striking features in the construction of the furnace are the deep-set grate and the contraction of the space between the bridge wall and the end of the prolonged fire-brick arch. The grate is 21 inches below the lower edge of the firing door. The object of this construction is to enable the fireman to carry a thick fuel bed and still see its condition at the top. The side furnace door used in removing clinkers, is only 7 inches above the grate.

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[a] Randall, D. T., and Kreisinger, Henry, North Dakota lignite as a fuel for power-plant boilers: Bull. 8, Bureau of Mines, 1912, 42 pp., 1 pl., 7 figs.

[b] Randall, D. T., and Kreisinger, Henry, op. cit., pp. 7, 8, 40.

METHOD OF OPERATING FURNACE.

The furnace is designed to work on the gas-producer principle. The solid fuel is gasified on the grate and the gas passes through the space under the arch into the combustion chamber, where most of the gaseous combustible burns. The necessary air for combustion is added through the openings in the bridge wall. This air is preheated to 200° to 300° F. in coils and forced into the furnace under a pressure of 0.5 to 1 inch of water. Owing to the location and direction of these air openings, the air is blown in jets into the comparatively slow moving body of combustible gas, thereby causing considerable stirring, so that the gases and the air form a fairly homogeneous mixture. A small quantity of air is also added through the openings in the roof of the furnace. Although there is some combustion above the fuel bed, the greater part of the gases burns below the contracted arch and back of the bridge wall, after air has been added through the openings. With rate of combustion exceeding about 25 pounds of coal per square foot of grate the flames extend even into the space above the arch.

The furnace is equipped with a rocking grate consisting of two rows of grate bars. Each row is connected with two shaking levers in such a way that by shaking one lever alternate bars in the row are rocked. Each grate bar is supported by a 2-inch pipe, through which cold air circulates; the object is to keep the grate bars and the ash immediately above them cool, so that the ash will not fuse and adhere to the cold bars.

The combination of boiler and furnace setting described gives good results with North Dakota lignite. Steam can be made with a fuel efficiency of 55 to 58 per cent of the heat in the coal, and no difficulty is experienced in obtaining the full capacity of the boiler.

COMMENTS ON THE EXPERIMENTS.

The tests mentioned showed results closely similar to those obtained by others who have used somewhat the same type of furnace construction in the burning of lignite. It is, therefore, plainly evident that great improvement can be made in the ordinary results obtained in burning lignite under boilers. In the experiments alluded to the lignite was crushed to the size in which it would give the best results. Too large lumps do not give even oxidizing surfaces. In some places the surface is insufficient and in other places the fire body is too open. As has been previously stated, a fire box properly filled with egg-size lignite gives a compact body of fire and still presents a much larger fuel surface.

IMPORTANCE OF PROPER FIRING OF LIGNITE.

Proper combustion of lignite, as was stated in a previous paragraph, depends largely on using a size of coal that will give an abundant air surface, but in addition a good draft should be so arranged that the air can be directed through the burning coal to the best advantage and can easily be controlled and closely shut down when it is desired to hold the coal at a relatively low heat. The fire box should be kept reasonably well filled, but the firing should be done frequently by the application of thin layers of fuel to the surface of the bed of hot lignite. The ash and clinker should be removed carefully and at sufficient rate to prevent an accumulation of clinkers.

Many firemen fail to get good results in the use of lignite because of uneven firing. The fire is allowed to run low and then a large quantity of the lignite, much of it in large lumps and carrying a high percentage of moisture, is introduced. The large addition immediately slackens the fire and materially reduces the temperature in the fire box, and, by the formation of considerable vapor, reduces still further the temperature of the gases, the heat from which should be left for boiler absorption. By such firing it is impossible to keep a uniform load with a high boiler efficiency, and much loss of fuel is experienced. By using coal of reasonably small size and firing in thin layers frequently, this difficulty is reduced to a minimum.

Many details contribute to success or failure in the utilization of lignite, and the features mentioned should be kept well in mind in selecting boilers, grates, and combustion chambers as well as in the method of operating and firing.

USE OF PULVERIZED LIGNITE.

IMPORTANCE OF PROPER COMBUSTION.

There is little doubt that the most perfect combustion of highly gaseous coals like lignites could be brought about by burning the pulverized material in a properly constructed combustion chamber in a draft of air. Such a method, to a limited degree, has been employed with bituminous waste for years in connection with several industries in which large ovens are used, but the machinery and appliances required have hitherto been too large and costly to permit their general adoption in small heating or boiler plants. There seems no good reason why some satisfactory method of using lignite in this manner in small plants can not eventually be evolved. Pulverization of highly gaseous lignites produces fuel with properties closely similar to those of crude petroleum or crude gas; in fact, pulverized highly gaseous coal like dry lignite, when fed into a furnace with an air blast, gives very largely a gaseous fuel.

ADVANTAGES OF THE METHOD.

With the temperature of the furnace or combustion chamber once at the proper point, by means of valves the relative supply of coal and air can be regulated so quickly and so perfectly that nearly complete combustion of the heat-producing constituents can be obtained. Besides, with the proper equipment, the feed and the fire should be closely uniform, almost automatic, and requiring comparatively little work from the fireman. When dry pulverized lignite can be used in small boiler settings to advantage, there is no reason why it should not produce a relatively high heating efficiency, for, in a proper combustion chamber, besides the combustion of fixed carbon, this method would utilize nearly all of the volatile gases, which have high calorific power, a proportion of which is lost by the ordinary methods of combustion to which lignite is subjected.

PRODUCER GAS FROM LIGNITE.

PROGRESS IN THE PAST 10 YEARS.

For the production of power in moderately large plants, it is clear that lignite coal can be used to advantage by converting it into producer gas and using the gas in an internal-combustion engine. During the past 10 years considerable progress has been made in the adaptation of producer plants for the use of lignite, and the results obtained in commercial plants scattered over several of the lignite States, and in tests made by the Government, indicate that this method of utilizing lignite can be successfully and economically employed in many instances and that there is an opportunity for considerable expansion in the use of this type of power producer.

PRINCIPLE OF MAKING PRODUCER GAS.

Producer gas is derived from the incomplete combustion of a rather thick bed of fuel held in a specially devised combustion and gas-producing chamber. Unlike the production of ordinary coal gas, there is little or no residue of coke left in the producer, but the coal is in part converted into gas by the combustion of the remaining part. To bring about this transformation to the best advantage and to supply a larger amount of hydrogen and carbon monoxide, steam is commonly introduced into the chamber during the burning of the coal.

RESULTS OF GOVERNMENT TESTS AT ST. LOUIS.

During the World's Fair in St. Louis, a model producer-gas plant was put in operation by the United States Government. Surprisingly successful results in the production of power gas were obtained by the use of widely different coals. Arrangements were made for the testing of two or three carloads of North Dakota lignite at the plant. The results were most satisfactory. North Dakota lignite used in the producer plant gave an excellent grade of producer gas. Similar tests were made with lignites from other localities, and with a large number of samples of bituminous, anthracite, and other grades of coal.

TABULATED DATA.

The composition of producer gas varies greatly with the different fuels from which it is derived. The following table, made from the results of tests reported by Fernald and Smith,[a] gives for each of several different grades of coal the analysis and relative heating and power-producing quality and the comparative consumption of coal per unit of power produced by use in the steam engine and the producer-gas plant.

Results of gas-producer and steam-engine tests of different grades of coal.

Item.	Virginia semi-anthracite coal.	Ohio bituminous coal.	North Dakota lignite.	Texas lignite.	Colorado lignite.
Carbon dioxide, per cent	10.2	9.0	8.69	11.10	10.11
Carbon monoxide, per cent	19.1	20.2	20.90	14.43	17.38
Hydrogen, per cent	20.5	15.3	14.33	10.54	11.05
Methane (CH_4), per cent	1.9	2.7	4.85	7.48	5.00
Nitrogen, per cent	48.2	52.3	51.02	56.23	55.91
Ethylene (C_2H_4), per cent	0.1	0.5	....	....	....
Heat units per cubic foot of gas, B. t. u	160.7	165.2	164.1	169.7	149.0
Dry coal consumed by producer plant, per switchboard per horsepower-hour, pounds	1.29	1.44	2.29	2.22	1.71
Dry coal consumed in steam engine, per switchboard per horsepower-hour, pounds	4.46	3.97	6.47	7.45	4.85

ADVANTAGES OF MAKING PRODUCER GAS FROM LIGNITE.

Although it is true that, per cubic foot, the heat value of producer gas is low as compared with that of natural gas or coal gas, it being about one-fifth that of ordinary city coal gas, the volume of producer gas derived from a ton of coal is so large as to more than compensate for the difference in value. Because of the relatively large volume of gas produced, and the ease and cheapness of the process, the final cost per thousand feet of producer gas is low.

LIGNITE PRODUCER GAS IN TEXAS.

Lignite has been considerably used for producer-gas purposes in Texas. In this connection Phillips[b] says:

> During the past few years there has been a marked increase in the use of lignite for making gas in gas producers. The gas thus made is used for power in gas engines of special design, or for fuel for burning lime, etc. So far as known the gas is not used in Texas for burning brick, sewer pipe, tiling, etc., although it would certainly be well adapted for such purposes.
>
> There have been installed in this State 56 producers for making gas. * * * The success that has been reached in the smaller plants indicates the adaptability of the producer and gas engine to requirements varying from 50 to 250 horsepower, quite as well as to the larger uses.

---

[a] Fernald, R. H., and Smith, C. D., Résumé of producer-gas investigations, Oct. 1, 1904, to June 30, 1910: Bull. 13, Bureau of Mines, 1911, pp. 108, 170, 174, 208, 212, 290, 292, 293, 294, 302, 304, 306.

[b] Phillips, D. McN., The use of producer gas in Texas: Univ. of Texas Bull. 189, 1911, pp. 59, 60, 61.

It is beyond question that a very active interest is now being shown in the use of producer gas made from lignite, and as experience is gained both in the handling of the various types of producers, and, more especially, in the design and construction of engines for using large volumes of gas of low-heating power, the use of lignite will be extended.

GENERAL VALUE OF PRODUCER GAS.

Fernald and Smith[a] have made a valuable and extensive report on producer-gas investigations. Pertinent abstracts[b] from their report follow:

> The abundance of natural gas and the multiplicity of uses to which it has been applied have led to a much greater appreciation of the advantage of gaseous fuel, and have helped to emphasize the value of the gas producer. During the past few years there has been great development in the utilization of producer gas, not only for power purposes and in the manufacture of iron and steel, but in other industries as well.
>
> ### SPECIFIC USES POSSIBLE.
>
> Among the uses to which producer-gas fuel has been put are annealing, japanning, enameling, soldering, brazing, galvanizing, drying, evaporating, tempering, case-hardening, type casting, yarn singeing, heating molds, wash kettles, ladles, stoves, baker's ovens, and cooking. It has also been used rather extensively in brick, lime, and cement kilns, and in various types of ore-roasting furnaces.
>
> ### RELATIVELY LOW-HEAT VALUE MUST BE CONSIDERED.
>
> In using producer gas as a fuel one should remember that the heat value of the gas is low compared to that of the other gases used for similar purposes, with the exception of blast-furnace gas. Natural gas has an approximate average heat value of 1,000 B. t. u. per cubic foot; the heat value of artificial or ordinary city gas is about 650 B. t. u. per cubic foot; whereas the heat value of producer gas ranges from 100 to 275 B. t. u. per cubic foot, according to the method of production. This relatively low-heat value must be taken into account when considering the method of application. In spite of its low-heat value producer gas is usually cheaper for work requiring relatively large quantities of gas than any other fuel, with the possible exception of natural gas sold at a low price.
>
> The introduction of producer-gas fuel for all types of service necessarily requires at the present time a certain amount of careful engineering promotion, owing to the uncertainty that exists regarding its successful use in fields in which natural or artificial gas or even solid fuels have been in vogue for years.
>
> In many possible applications of producer gas as a fuel there seems to be little if any gain over direct firing with coal. Opinions differ regarding this point, many claiming that there is always a considerable saving in favor of producer gas. The difference either way is probably small, but other considerations are frequently of such importance as to give producer gas a great advantage. Under conditions requiring uniformity of temperature for continued periods, or variations in temperature at positive intervals, the ease with which the supply of producer gas can be regulated insures results that would be entirely impossible with solid fuel. Producer gas may also be employed with comparative ease as a reducing agent.

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[a] Fernald, R. H., and Smith, C. D., Résumé of producer-gas investigations, October 1, 1904, to June 30, 1910: Bull. 13, Bureau of Mines, 1911, 393 pp., 12 pls., 250 figs.

[b] Fernald, R. H., and Smith. C. D., op. cit., pp. 34, 35, 36.

Under the simple conditions required for boiler heating, it is questionable whether any advantage is to be obtained by the use of producer gas except, possibly, where low-grade fuels are burned. There are many fuels that can be utilized to advantage in the gas producer that can not be employed in direct steam-boiler firing.

GENERAL COMMENTS.

There are many advantages to be gained in converting low-grade fuel into gas when the uses to which it is to be put and other conditions will permit. Of course for many purposes such conversion can not be made, but for power and for many industrial purposes such gas has the advantage of being readily controlled, so far as the intensity and the application of heat are concerned, and it may be handled with little labor compared with that required when coal is used in the ordinary condition.

Producer gas from lignite would undoubtedly make a highly satisfactory fuel for use in burning brick and other clay products and, although it has not been so utilized to any great extent up to the present, it is, however, attracting the attention of the manufacturers of such products.

In 1910 it was estimated that 4 per cent of the producer plants in use were operating upon lignite. It is probable that the success thus far attained by these plants will soon stimulate a much more extensive use of lignite producer gas for certain types of power plants.

BRIQUETTED LIGNITE.

BRIQUETS COMPARED WITH OTHER FUEL.

At the present time undoubtedly by far the largest use of lignite is for domestic purposes—in heating plants, stoves, ranges, etc. For such use most of the lignite is supplied in sizes ranging from large lumps to pieces about the size of those in slack, careful sizing being employed rarely. The lignite is generally used in the most simple manner. Few special methods for burning or utilizing the lignite or for specially preparing it for the market have been adopted. However, there can be little doubt but that for most purposes, particularly for general stove and furnace use, briquetted lignite would be the most desirable form in which the lignite could be presented on the market; and lignite briquets of good quality and at a reasonable price should prove a most satisfactory and profitable fuel. Considerable success has been attained in the briquetting of both anthracite and bituminous coal wastes, and the lignites of Germany have been briquetted with some degree of success. But the briquetting of anthracite and bituminous coal waste is an entirely different problem from the briquetting of lignite, and the difficulties to overcome are comparatively simple. The German lignite also is of such character and composition that it can be briquetted with comparative ease. Furthermore, when binding materials are required for the German lignite, such materials and the labor necessary can both be obtained at a much lower cost in Germany than in this country.

However, the process briefly explained in the following pages is proving so successful in the experimental plant that there now seems little doubt but that if a briquetting plant, in conjunction with a gas-producing plant, is operated according to the principles and methods described a variety of by-products can be saved and utilized and that the residue, after the gas has been driven off, can be successfully briquetted into a concentrated and valuable fuel.

THE PRODUCTION OF LIGNITE GAS.

GASEOUS CONSTITUENTS OF LIGNITE EASILY DISTILLED.

Repeated experiments with lignite have made it clearly evident that lignite contains in addition to its high moisture content two widely different fuel constituents, namely, a large proportion of light gases, which pass off at a comparatively low temperature, leaving a residue in character between coke and charcoal, which requires a much higher temperature for combustion and burns more slowly than the lighter constituents. The residue does not coke, but remains as powder or slack, which checks the draft and is slow in oxidation. The gases, however, are volatile and are easily driven off from the coal at a comparatively low temperature. As a result they are distilled off quickly in the ordinary methods of burning and are either burned with a flashy flame or are lost, in a large degree unconsumed, with the flue gases. Thus there is an uneven combustion of lignite, and it is impossible with the ordinary type of furnace and fire box to obtain a high degree of efficiency in its consumption.

PRELIMINARY LABORATORY EXPERIMENTS.

The first work in a systematic research as to the production of gas from lignite coal and the utilization of the by-products was of a preliminary nature. It was carried on in a small way with laboratory apparatus in testing a large number of lignite and ordinary gas coals for the purpose of obtaining a general idea of the comparative quality and character of the gas, tar, and residue produced by each of the coals, of the temperature required for most efficient work with the various coals, and of the probable amount of ordinary by-products obtainable from each under the conditions employed.

The lignite samples, collected from different areas by the author and his assistants, were subjected to a great variety of preliminary tests.

This work required much time and labor, but gave most valuable information which was utilized in planning the later and more systematic attacks on lignite-gas problems. The results proved conclusively that the gas from the lignites of different deposits is closely similar, that it may be removed at nearly the same temperature, and that a residue and by-products of a general similarity are left although the quantity of each varies considerably. The main products and by-products thus obtained were compared with those obtained from ordinary gas coals tested by the same processes. All of this preliminary work was most suggestive as to the possibility of the profitable production of lignite gas.

EXPERIMENTAL-LABORATORY EQUIPMENT.

The next step in the investigation was the designing and erection of a small working lignite plant adapted to laboratory methods but of sufficient size to approximate more closely the methods that might ordinarily be used in the manufacture of gas from lignite.

The plant was constructed and operated as follows:

A cast-iron retort is arranged so as to form a small gas bench similar to that ordinarily used in gas works. The retort has a capacity of about 40 pounds at a charge and is heated by a coal-fired bench. The retort is fitted for pyrometer tubes, and readings are taken constantly during each run.

Provision is made for running small charges of coal by the use of a small furnace and retort. For special purposes when it is desirable to use a still smaller quantity of coal a second smaller retort is used. This has a capacity of 5 pounds of coal. By a system of connections and valves either the large or the small retort can be by-passed. The main connection leads from either retort to the tar extractor, which serves to collect those products that condense the most readily at higher temperatures. The extractor consists of two cones so arranged that the gas must whirl around the inside cone before reaching the outlet; the condensed material is gradually drawn to a point where it is delivered to a small cylinder provided with a full-way valve for completely discharging the tar and other condensed matter into a measuring cylinder.

From the extractor the gas passes to the condenser, which consists of tubes arranged to drain to the lowest section and provided with a valve for discharging. The condenser tubes are surrounded by circulating water. Beyond this is the scrubber provided with a sprayer, coke trays, etc. From the scrubber the gas passes to the purifier, which is provided with two sets of purifier compartments so that the gas can be made to pass through either one or both sets of compartments. One set is fitted with lime for removing carbon dioxide, and the other set is supplied with iron oxide. An exit pipe leads from the purifiers to the gas holder, which is a large size meter prover, with a capacity of 10 cubic feet. This prover or gas holder is carefully calibrated and provided with an accurately graduated scale indicating the contents in cubic feet and hundredths of a cubic foot. The holder is arranged to supply any pressure desired and to give a uniform pressure with any quantity of gas. It is provided with thermometers, pressure gages, etc. From the holder the gas is piped to the gas-testing laboratory, on the floor directly above the gas plant. In this laboratory are made the chemical analyses and also a great variety of practical burning tests for heat and lighting qualities. The calorific tests are also made here by the use of a standarized gas calorimeter.

SPECIALLY DESIGNED PLANT.

The small plant just described, at the University of North Dakota school of mines, at Grand Forks, N. Dak., was the forerunner of the larger specially designed briquetting and gas plant at the mining substation at Hebron, N. Dak. (Pls. I and II), where both briquetting and gas problems are being worked out on a scale so large as to insure results applicable to commercial practice. The briquetting press is capable of turning out 2 tons of briquets per hour, and the gas plant is a full-size unit, complete, and of the standard type of construction.

The equipment of the large experimental gas plant at the mining substation consists of a bench of one retort, one condenser, one exhauster, two scrubbers, one purifier, and one meter, all of the full size used in commercial plants, and one gas holder and miscellaneous apparatus necessary for the proper operation of the plant.

The gas bench is substantially constructed. Its dimensions are 11 by 6½ by 7¾ feet. The foundation, 1 foot thick, is built of common brick.

The bench contains one standard clay retort 1¼ by 2⅛ by 9 feet. The retort is 4 inches thick throughout, with the exception of the head, which is made heavier and thicker to receive the mouthpiece. As the retort is the standard size used in gas works, it is capable of carbonizing about 400 pounds of coal in four hours, with a retort temperature of 1,200° to 1,800° F.

The bridge wall is in the center of the bench and extends from the bottom of the firebox to the top of the retort. The wall is 9 inches thick, and is built of fire brick. It causes the gases from the furnace to burn upward around the retort in the front end of the bench and downward in the rear end. Hence the top and bottom of the retort are heated equally and an even temperature is obtained. The retort is provided with a cast-iron self-sealing mouthpiece 15 by 26 inches.

The chimney is 9 by 13 inches and is placed at the back of the bench. It extends from the lower combustion chamber, underneath the retort, to the top of the bench. Near the bottom of the chimney is a damper, by which the draft can be regulated. A steel stack 15 feet high surmounts the chimney and extends through the roof of the building.

The hydraulic main consists of a 2-foot length of 32-inch pipe. The ascension pipe from the retort is connected with the dip pipe of the hydraulic main by a 10-inch tee. On the opposite side of the main is a 4-inch outlet service to the condenser.

Attached to one end of the hydraulic main, and connected with it by an elliptical opening, is a 15-inch, cubical, cast-iron box. This box is provided with a tar-drain regulator and a drain-water connection to a water gage.

The tar-drip regulator is of special design and can be regulated so that the hydraulic main can be operated without a water seal, or with any desired seal up to 4 inches.

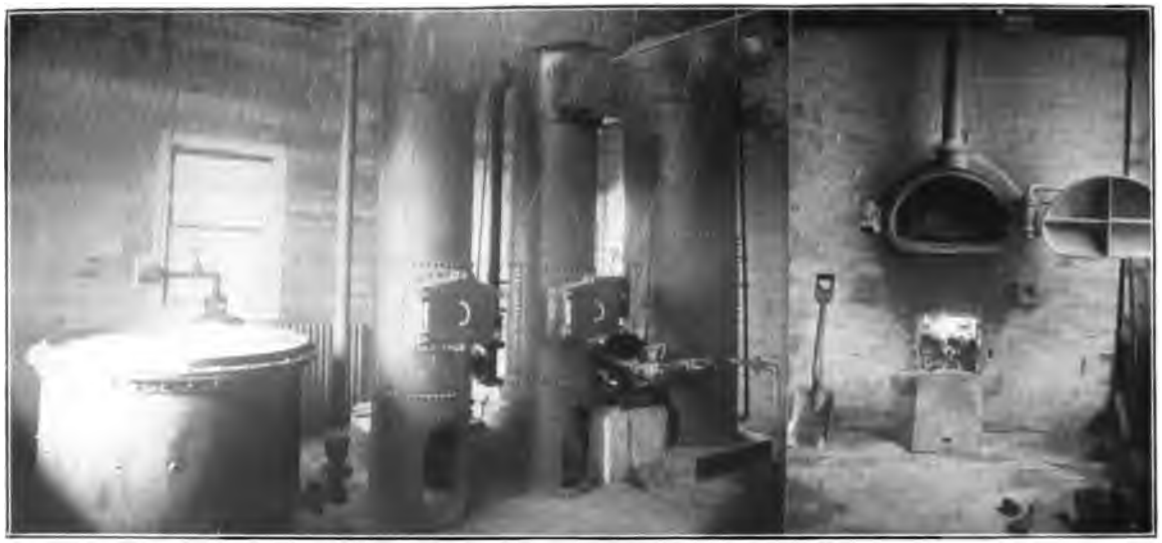
In the bottom of the box, and at the lowest point in the hydraulic main, is a 2-inch outlet pipe. This pipe can be opened or closed by a valve and is connected with the tar barrel. By means of this drain all the tar and ammoniacal liquor can be drained out of the hydraulic main after each experimental run. The advantage of this arrangement is that fresh water can be used on each new charge, and the danger of accumulated tar absorbing illuminants from the gas is avoided. Further, the products from each experiment can be accurately weighed and determined.

A standard water-tube condenser is used to remove the tar, coke dust, and pitch, and to condense the superfluous water vapor. The condenser is 3 feet in diameter by 11 feet high, and it contains 21 water tubes 3 inches by 8 feet.

The cooling water enters the base of the condenser and flows upward through the tubes into the reservoir at the top, which is provided with an overflow pipe that leads into a sump outside the building. The supply of water to the condenser can be regulated so that the gas can be cooled to any desired temperature above that of the inlet water.

The gas enters the condenser through a 4-inch tube and passes downward around the water tubes to the outlet at the bottom. The water flows in a direction opposite to that of the gas, so that by the time it reaches the inlet of the condenser it has, by absorbing the heat of the gas, attained a comparatively high temperature, and thus any sudden cooling of the gas at the entrance is avoided.

The bottom of the condenser is provided with a 2-inch tar outlet, through which the tar, ammoniacal liquor, etc.. can be discharged into a tar tank.



PART OF LIGNITE-GAS PLANT AT EXPERIMENTAL SUBSTATION AT HEBRON, N. DAK.

The exhauster is a No. 1 Root and is provided with a 3-inch gas inlet and outlet. It consists of a vertical steam engine direct connected to the exhauster and mounted on a heavy cast bedplate.

The speed of the exhauster can be made to vary in accordance with the volume of gas being generated in the retorts. The speed is regulated by an automatic steam valve which permits uniform pressure at whatever gage desired.

Two cylindrical tower scrubbers are used to remove the last traces of tar, ammonia, and other impurities. The scrubbers are constructed of sheet steel three-sixteenths of an inch thick and are 24 inches in diameter by 8 feet high. The scrubbers are filled with wooden trays, supported on a steel angle ring.

The liquor used in the scrubber is admitted into the head through a 1-inch pipe, and is distributed equally over the surface of the tray by a sprayer. Fresh water, sprayed into the top of scrubber No. 2 by an overhead flushing apparatus, absorbs practically all the ammonia remaining in the gas, which enters from below and flows into a 100-gallon ammonia-liquor tank; from here the weak liquor is lifted by a centrifugal pump to the top of scrubber No. 1 to thoroughly wet its filling material. The liquor from scrubber No. 1 also passes by a trapped drain into the ammonia sump, and thus there is a continuous circulation of weak liquor. The top of the ammonia tank is well covered to prevent loss of ammonia by evaporation. By this process a part of the carbonic acid and sulphuretted hydrogen, as well as other sulphur compounds, are removed, the lime and oxide purifiers being thus relieved; the weak liquor is also brought to the requisite commercial strength.

The purifier is used to remove, or reduce to a negligible quantity, the carbonic acid and sulphuretted compounds in the gas. It is a sheet-steel, cylindrical box 4 feet in diameter by 2½ feet deep and is provided with 3-inch inlet and outlet gas pipes. The purifying material is supported on wooden trays. The purifier has not been used much on the gas produced from lignite, for although the gas is high in carbon dioxide it is nearly free from sulphur. The purification, however, materially raises the heat value of the gas.

An accurate meter is used to measure the volume of gas generated in each experimental run.

The gas holder consists of a holder 9¾ feet in diameter by 13½ feet deep, erected in a steel tank 10¾ feet in diameter by 13 feet deep. This holder is accurately calibrated and thus serves to check the meter readings.

The pressure of the gas can be conveniently taken in any part of the plant by a central differential gage 24 inches high and provided with a scale graduated to tenths of an inch. It is connected with the various parts of the plant.

The appliances for taking the temperature and pressure of the gas are arranged so that the operator can, by throwing a switch, read at his desk the temperature or pressure at any part of the plant. This arrangement is not only convenient and a saving of labor, but it is helpful in accurate scientific work.

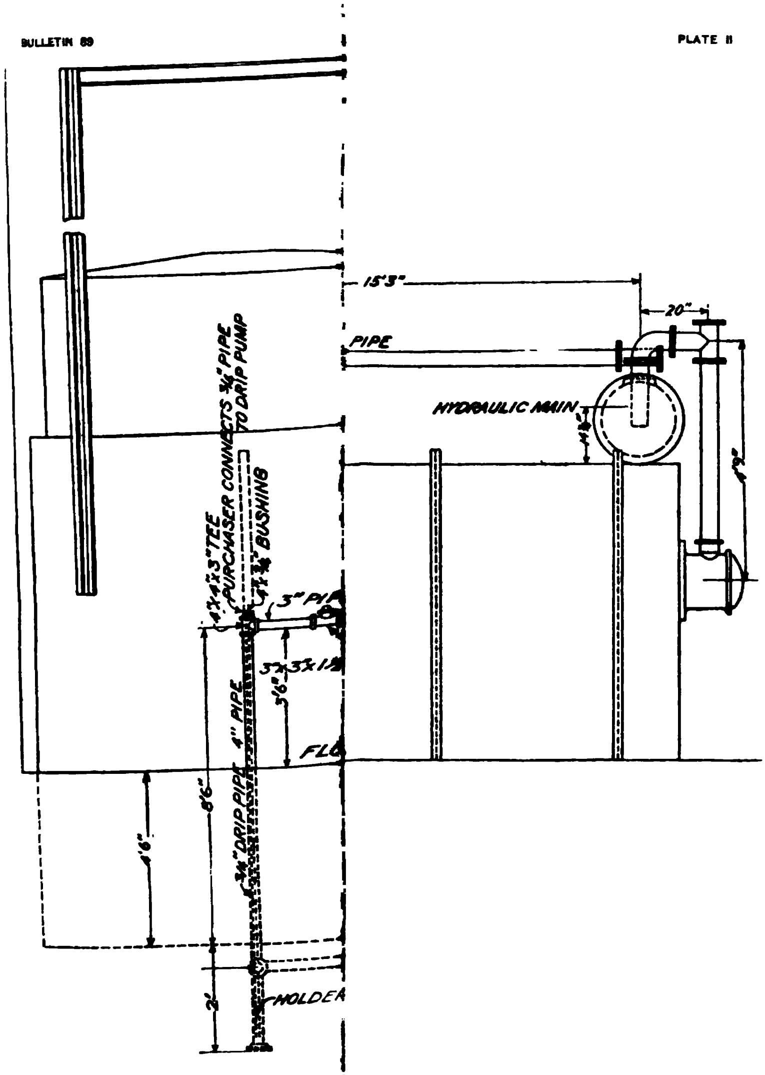
GENERAL RESULTS OF EXPERIMENTAL WORK.

The large number of experiments performed during the progress of the work in the laboratory and in the plant just described indicate that one of the methods offering the greatest possibility in the utilization of lignite is that of producing gas in a retort and utilizing the retorted residue and by-products. In carrying out this process, four products are obtained. First, in the use of comparatively dry lignite a large yield of gas is procured, the gas being of a quality adapted for power and for heating and lighting purposes. Second, after the gas has been driven off the lignite is converted into a noncoking residue of good quality, having a high percentage of fixed carbon and excellent heat-producing properties. Third, a tar is obtained which, with proper distillation or concentration, gives a product promising to be of considerable commercial value. The preliminary experiments thus far carried on would indicate that by special treatment the tar can be advantageously used in the process of briquetting. It also contains other products of evident worth. Fourth, a product is derived containing a large yield of ammonia which, after being converted into ammonium sulphate, may have considerable market value.

During the tests of the past two years careful observations were made to determine the temperature required, the amount of gas produced, the amount of coal residue left, and the quantity and character of tar and ammonia by-products. Careful analyses and calorific determinations of the gas were then made. In this manner much valuable information has been procured. The amount and character of the gas obtained from lignite has been rather surprising and very encouraging. Indeed, there seem to be great possibilities in the manufacture of gas from lignite, especially if all of the by-products are carefully utilized.

PROCEDURE IN EXPERIMENTS.

The lignite used for experimental work was gathered from many mines included in a wide area in the State of North Dakota, and from mines in Montana, Wyoming, Colorado, and Texas. The samples were procured in considerable quantities and were carefully analyzed and air dried to various degrees before being used in the gas plant. In addition to the tests of lignite, runs were made on


15'3"
20"
PIPE
HYDRAULIC MAIN
14½"
4'9"
4"×4"×3" TEE
PURCHASER CONNECTS ¾" PIPE TO DRIP PUMP
4"×¾" BUSHING
3" PI
3"×3"×1½
5'6"
FLO
4" PIPE
¾" DRIP PIPE
8'6"
4'6"
2'
HOLDER

other kinds of bituminous gas-producing coals to permit a comparison as to operating results and the products procured. By the use of samples from so many districts equitable average results were obtained.

The type of construction of the gas plant permitted its being operated in a manner closely similar to that employed in many commercial gas plants. Every step of the operation was carefully watched and made to approach as nearly as possible the methods that might ordinarily be expected to be required for economic production. The quality of gas produced by the plant is probably inferior to that which could be procured in a large commercial plant, owing to the fact that in stopping and starting and carrying on the experimental work there is frequently introduced into the retorts, apparatus, and pipes varying amounts of air—a condition that can not be eliminated in an experimental plant. Consequently, the gas contains an unduly large proportion of carbon dioxide and of residual air.

Nevertheless, the plant has given excellent results and, as regards the amount and quality of gas that can be derived from lignite coal, indicates much wider possibilities than were expected. There was generally used for each charge of the retort 400 pounds of air-dried coal, the moisture content of which was definitely known. The coal was crushed to an average size which would pass through a 2-inch ring. The lid of the retort was well clamped and sealed, and the temperature raised gradually to the required degree. A series of experiments was conducted to determine the temperature giving the largest quantity and the best quality of gas. It was found that the gas distilled freely at 900° to 1,000° F., whereas the proper temperature to give the maximum quantity and quality of gas seemed to be between 1,200° and 1,400° F. High-temperature readings were made by the pyrometer, along with simultaneous records of the rate of gas production. At frequent intervals gas samples were obtained for analyses. The desired heat was carefully maintained until the evolution of gas ceased, after which the valves were closed, the retort was cooled, and the noncoking residue was cooled and carefully weighed. The gas was passed successively through the tar extractor, the condenser, the scrubber, the purifier, and finally to the gas holder, where the quantity was accurately read off from a scale connected with the holder, careful corrections to normal temperatures and barometric pressure being made.

After the gas had been measured and analyzed and had been tested in the calorimeter to determine its heat value, it was used with different types of burners and in various practical ways to demonstrate its efficiency as a fuel gas. As regards the by-products, the tar was separated from the water and weighed and the ammonia was separated and its quantity determined. The resulting proportion of noncoking retort residue remaining was also determined, and an analysis was made to ascertain the percentages of fixed carbon, volatile matter, and ash. By the use of such data the composition of the residue could be compared with that of the original lignite and also with that of bituminous and anthracite coal.

The methods of coal and gas analysis employed were those adopted by the fuel-testing section of the United States Bureau of Mines and in the best practice by gas experts. The calorimeter determinations were made with a properly standarized gas calorimeter.

TABULATED DATA.

The following tables give average results of tests of a large number of widely different but representative coals. The greater number of the tests were made with North Dakota lignites from various parts of the State, but lignites from Montana, Colorado, and Texas were also represented.

Gas yields and heating values of representative lignite samples.

Sample No.	Unpurified gas.		Retort temperature.	Sample No.	Unpurified gas.		Retort temperature.
	Yield per ton of air-dried lignite.	Calorific value.			Yield per ton of air-dried lignite.	Calorific value.	
	Cubic feet.	*B. t. u.*	°*F.*		*Cubic feet.*	*B. t. u.*	°*F.*
1	12,298	363	1,700	15	9,759	404	1,430
2	11,676	348	1,500	16	10,877	385	1,560
3	13,297	285	1,600	17	9,335	435	1,360
4	13,108	384	1,600	18	10,160	415	1,270
5	11,092	392	1,720	19	9,460	420	....
6	11,770	372	1,650	20	11,730	411	....
7	10,300	392	1,500	21	9,124	425	1,764
8	12,835	390	1,560	22	8,368	434	1,300
9	10,663	401	....	23	9,623	476	1,200
10	11,306	407	1,510	24	11,450	334	1,650
11	11,801	400	1,540	25	7,825	487	1,110
12	12,525	379	1,510				
13	12,803	382	1,510	Average	11,038	396	1,498
14	12,160	387	1,385				

Results of analyses of gas from representative lignite samples.

Sample No.	Illuminants.	Carbon monoxide.	Hydrogen.	Ethane.	Methane.	Nitrogen.	Oxygen.	Carbon dioxide.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	0.90	23.85	43.90	0.16	13.88	8.76	0.75	7.80
2	1.00	25.56	44.55	.90	7.06	15.43	4.00	1.50
3	1.30	19.85	38.78	.33	12.78	13.26	1.90	11.80
4	.65	28.02	45.07	.73	13.83	4.70	.30	6.70
5	.55	25.02	44.00	.00	11.83	10.90	1.00	6.70
6	2.27	17.49	46.34	.00	15.89	3.67	.55	13.79
7	1.80	23.61	44.12	.29	8.80	13.88	2.78	4.72
8	2.55	17.00	50.30	.16	13.52	5.59	3.03	7.85
9	2.15	22.45	47.63	1.79	10.41	5.27	.95	9.35
10	1.85	22.70	43.61	.09	15.67	5.28	.90	9.90
11	1.45	27.75	41.85	.15	10.44	7.11	.85	10.40
12	2.25	21.75	40.26	.81	12.72	3.76	.45	18.00
13	1.30	20.44	27.11	.16	13.18	22.16	5.55	10.10
14	2.35	19.15	40.60	.00	14.55	11.55	1.35	10.45
15	1.20	14.05	14.10	.13	10.50	42.27	10.50	7.25
16	.75	21.13	28.24	.24	16.72	14.62	1.30	7.00
17	3.38	20.61	38.52	.00	19.72	3.28	.95	13.53
18	2.60	12.80	43.70	.00	23.10	9.40	1.70	6.70
19	.65	22.34	45.99	1.55	13.13	5.59	1.10	9.65
20	1.70	17.90	44.60	.00	16.60	4.80	.30	14.10
21	.80	9.95	32.93	.00	31.62	.40	2.10	22.20
22	3.40	14.70	40.00	.00	19.90	8.80	1.40	11.80
23	3.10	15.30	41.70	.00	18.10	7.40	1.10	13.30
24	3.60	18.20	36.10	.00	19.20	8.50	.60	13.80
25	3.38	20.61	38.53	.00	19.72	3.28	.95	13.53
Average	1.88	20.09	40.10	0.30	15.31	9.98	1.86	10.48

Residues yielded by representative lignite samples.[a]

Sample No.	Yield per ton of coal as charged.	Proportion of lignite charged represented by residue yield.	Sample No.	Yield per ton of coal as charged.	Proportion of lignite charged represented by residue yield.
	Pounds.	*Per cent.*		*Pounds.*	*Per cent.*
1	1,078	53.90	15	1,066	53.30
2	1,071	53.55	16	1,085	54.25
3	1,035	51.75	17	1,208	60.40
4	1,137	56.85	18	1,046	52.30
5	1,129	56.45	19	1,198	59.90
6	1,140	57.00	20	891	44.55
7	1,161	58.05	21	1,236	61.80
8	1,051	52.55	22	1,081	54.05
9	1,137	56.85	23	1,140	57.00
10	1,130	56.50	24	1,000	50.00
11	1,108	55.40	25	870	43.50
12	1,103	55.15			
13	1,110	55.50	Average	1,092	54.60
14	1,078	53.90			

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[a] The samples were partly air dried, containing 8 to 27 per cent moisture.

Calorific values and results of analyses of lignite residue.

Sample No.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Calorific value per pound of residue.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*B.t.u.*
1	1.91	5.87	74.71	17.51	1.54	11,738
2	8.38	6.97	62.93	21.72	2.88	10,055
3	.31	9.86	74.67	15.16	1.48	12,207
4	.00	6.48	73.86	19.66	1.53	11,149
5	2.03	6.60	75.20	16.17	1.45	11,506
6	.57	7.88	72.38	19.17	2.27	11,399
7	.00	8.08	75.46	16.46	1.91	11,681
8	.00	9.45	74.00	16.55	1.93	11,589
9	.00	9.20	73.20	17.60	3.04	11,558
10	.00	8.60	73.84	17.56	2.49	11,618
11	.00	8.09	74.58	17.33	2.09	....
12	.00	9.00	72.96	18.04	2.06	....
13	1.68	7.04	73.88	17.40	....	....
14	4.90	8.76	67.19	19.15	....	....
15	1.85	10.64	69.78	17.73	....	....
16	.80	3.10	75.95	20.15	1.27	9,740
17	.00	15.85	74.30	9.85	....	12,905
18	.00	.90	90.50	8.60	....	....
19	.00	4.11	77.25	18.64	....	12,820
20	.00	12.70	77.05	10.25	....	11,940
21	.35	8.05	80.60	11.00	....	12,240
22	.00	7.00	81.40	11.60	....	12,442
23	.00	7.97	85.19	6.84	....	15,035
24	.00	15.07	68.80	16.13	....	11,451
25	2.15	2.01	78.34	17.50	1.79	....
Average	1.00	7.57	75.52	15.91	1.98	11,838

Average results of gas tests of 10 North Dakota lignite samples.

Analysis of coal:	Per cent.
Moisture in lignite as received (partly dried)	6.98
Volatile matter (partly dried)	39.50
Fixed carbon (partly dried)	44.64
Ash (partly dried)	8.88
Heating value of lignite (partly dried), B. t. u. per pound, 10,160.	
Yield of unpurified gas from partly dried lignite, cubic feet per ton, 12,487.	
Analysis of unpurified gas:	
Illuminants	1.49
Carbon monoxide	22.52
Hydrogen	44.44
Methane	12.84
Ethane	.36
Nitrogen	7.88
Carbon dioxide	9.15
Oxygen	1.32
Residue yield from partly dried coal	55.34
Analysis of dry residue:	
Volatile matter	7.99
Fixed carbon	73.97
Ash	18.04
Heating value, B. t. u. per pound, 11,710.	

Average results of gas tests of four Montana lignites.

	Per cent.
Analysis of lignite:	
Moisture in lignite as received	9. 55
Volatile matter in dry coal	38. 20
Fixed carbon in dry coal	44. 90
Ash in dry coal	16. 90
British thermal units per pound (coal as received), 8,675.	
Yield of unpurified gas from lignite as received, cubic feet per ton, 10,243.	
Analysis of unpurified gas:	
Illuminants	3. 2
Carbon monoxide	16. 2
Hydrogen	40. 0
Methane	21. 8
Nitrogen	7. 3
Oxygen	1. 0
Carbon dioxide	10. 5
Heating value, B. t. u. per cubic foot, 445.	
Yield of residue from lignite as received	57. 8
Analysis of dry residue:	
Volatile matter	5. 3
Fixed carbon	72. 0
Ash	22. 7
Heating value, B. t. u. per pound, 9,740.	

Average results of gas tests of Colorado lignites.

	Per cent.
Analysis of lignite:	
Moisture in lignite as received	17. 2
Volatile matter in air-dried lignite	36. 38
Fixed carbon in air-dried lignite	57. 74
Ash in air-dried lignite	5. 88
Heating value of lignite as received, B. t. u. per pound, 10,348.	
Yield of unpurified gas from lignite as received, cubic feet per ton, 8,746.	
Analysis of unpurified gas:	
Illuminants	3. 20
Carbon monoxide	14. 25
Hydrogen	40. 90
Methane	19. 95
Nitrogen	7. 10
Oxygen	1. 05
Carbon dioxide	13. 55
Heating value, B. t. u. per cubic foot, 429.	
Yield of residue from lignite as received	53. 78
Analysis of dry residue:	
Volatile matter	. 9
Fixed carbon	90. 5
Ash	8. 6

Average results of gas tests of three Texas lignites.

	Per cent.
Analysis of lignite:	
Moisture in lignite as received	11. 15
Volatile matter in air-dried lignite	44. 90
Fixed carbon in air-dried lignite	44. 99
Ash in air-dried lignite	10. 11
Heating value of lignite as received, British thermal units per pound, 9,943.	

Yield of unpurified gas from lignite as received, cubic feet per ton, 10,557.

Analysis of unpurified gas:	Per cent.
Illuminants	1.53
Carbon monoxide	16.94
Hydrogen	39.26
Methane	18.85
Nitrogen	6.56
Oxygen	.43
Carbon dioxide	16.43
Heating value, British thermal units per cubic foot, 335.	
Yield of residue from lignite as received	52.11
Analysis of dry residue:	
Volatile matter	6.76
Fixed carbon	75.94
Ash	17.30
Heating value, British thermal units per pound, 12,836.	

COMMENTS ON TABULATED DATA.

The results presented are typical of those from several hundred tests conducted. During the work several hundred tons of lignite was carbonized, and probably 1,000,000 to 2,000,000 cubic feet of lignite gas was produced.

It has been necessary, from start to finish, to develop the whole process for the treatment of lignite. During the work many peculiarities of lignite, lignite gas, residue, and by-products, as well as peculiarities and difficulties in the adaptation of the process of treatment have been encountered and in a great measure overcome. The method evolved seems to be thoroughly practical and to possess many commercially attractive features.

TEMPERATURE OF CARBONIZATION.

IMPORTANCE OF DISTILLATION TEMPERATURE USED FOR ANY COAL.

In the production of gas from coal, whatever the variety of coal used and whatever the type of retort or oven in which the gas is generated, the temperature required and the time necessary to remove the gas are important practical considerations. Not only is there a great difference in the products derived at different temperatures, but there is also a great difference in the necessary cost of operation.

Because the length of life of the retorts or ovens is rapidly reduced as the temperature to which they are subjected is increased, and because the operating expenses are greatly increased by the necessity of high-temperature distillation, it is a matter of double consequence to procure materials and to use methods that will permit a high degree of carbonization at as low a temperature and in as short a period as is consistent with the recovery of gas and by-products of satisfactory quality.

In the production of gas from ordinary bituminous coals there has been considerable discussion among practical and technical authorities as to the relative merits of high and low temperature distillation. It may be said that products of somewhat the same characteristics as those obtained in the treatment of bituminous coal are met with to a certain degree in the treatment of lignite, but the conditions necessary for obtaining the best results in the carbonization of lignites are widely different from those demanded for bituminous coal. Much of the lignite as mined contains 30 to 35 per cent moisture. The question that immediately rises is as to the effect of this moisture on the gases, residue, and by-products and also on the time and temperature required for carbonization.

INFLUENCE OF MOISTURE CONTENT OF LIGNITE ON TEMPERATURE OF DISTILLATION.

In the experiments it was quickly found that in the use of the ordinary gas retort of standard size the large proportion of water in the lignite immediately reduced the retort temperature, thereby delaying the time at which the distillation of gas began, and at the same time additional fuel and labor were required to bring the retort temperature back to the heat required for carbonization; thus there was an immediate loss of time, fuel, and labor in the use of lignite with its normal moisture content, and unless the yield of gas and by-products in quantity or quality would repay for the losses it was evident that it would be advisable to at least partly dry the lignite before introducing it into the retort. Accordingly many experiments were performed to ascertain the yield and quality of gas and the residue and by-products recovered from the distillation of lignite with the moisture content as high as when mined.

The results of the investigations indicate clearly that, as explained later, the proper retort temperature for lignite carbonization seems to be about 1,200° F., and at that temperature the retorting of wet lignite increases the quantity of gas but greatly reduces its quality, producing a relatively large volume of the oxides of carbon usually accompanied by a reduction of residue.

USE OF ROTARY DRIER.

The losses in the quality of the gas and in the residue are far from being compensated for by the increased yield of gas, to say nothing of the loss of fuel and labor required in maintaining the proper temperature of the retort. For this reason there is no question but that the lignite as mined should either be air dried or passed through some type of drier capable of rapid and cheap removal of the moisture. For this purpose the experiments indicated that a rotary drier of the standard type used for drying coal and a variety of other materials is highly satisfactory and economical. By means of a gentle heat, produced from lignite mine waste, the moisture content of run-of-mine lignite can readily and economically be reduced to 5 to 8 per cent.

This type of drier seems to be well adapted to this purpose. The lignite, after having been passed through the drier, is generally reduced to small lumps, which can be used to much better advantage than the large sizes in the retort or carbonizing oven. When lignite thus dried is used the gas begins to distill off quickly at a retort temperature of 1,200° F. and the time of retorting is much reduced. It is further found that the quality of the gas is greatly improved, the oxides of carbon being greatly reduced, and the residue seems to be better and larger than when undried lignite is used.

TABULATED DATA SHOWING EFFECT OF MOISTURE CONTENT ON YIELD FROM RETORTED LIGNITE.

There is, therefore, no doubt about the advisability of using reasonably dry lignite if the gas produced is to be used for lighting or other domestic purposes. The following tables show clearly the effect of moisture on the yield and quality of wet and dry lignite retorted at the same temperatures.

Results of tests of effect of temperature and moisture on quality and yield of lignite gas from lignite mine-waste slack.

Sample No.	Moisture content.[a]	Temperature.	Time.	Yield of gas per ton of fuel.	Analysis of gas.						
					Illuminants.	Carbon monoxide.	Hydrogen.	Methane.	Nitrogen.	Oxygen.	Carbon dioxide.
		°F.	Hours.	Cubic feet.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
1	Dried	300	1	50	0.0	0.0	0.0	0.0	81	19	0.0
2	.....do	300	2	76	.0	.0	.0	.0	81	19	.0
3	.....do	300	3	83	.0	.0	.0	.0	81.2	18.6	.2
4	.....do	600	1	575	.0	.1	.0	.0	81.3	18.4	.2
5	.....do	600	2	810	.0	.4	.0	.0	80.7	16.8	2.1
6	Wet	600	2	91.2	.7	4.9	4.6	3.1	58.6	10.9	17.2
7	Dried	900	1	2,807	.0	4.2	.0	.0	74.2	15.2	5.8
8	.....do	900	2	3,000	.7	7.0	11.1	6.0	59.1	11.9	14.2
9	Wet	900	2	1,828	1.6	1.6	1.26	11.14	23.8	3.2	57.4
10	Dried	1,200	1	4,114	1.4	11.1	15.9	6.6	17.1	1.1	46.8
11	.....do	1,200	2	4,268	1.3	10.9	17.0	15.9	7.6	1.2	46.1
12	.....do	1,200	3	4,275	1.5	9.9	17.8	16.9	6.8	1.2	45.9
13	.....do	1,500	1	7,396	1.2	16.7	27.5	16.4	6.7	1.1	30.4
14	.....do	1,500	2	7,502	1.4	17.3	31.9	15.0	5.0	1.1	28.3

[a] "Wet" means a moisture content of 28 per cent present in the sample.

Results of tests to indicate yield of lignite residue at various temperatures.

	Temperature of retort.	Time of run.	Yield of residue.	Calorific value per pound of coal.	Analysis.			
					Moisture.	Volatile matter.	Fixed carbon.	Ash.
	°F.	*Hours.*	*Per cent.*	*B. t. u.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Lignite as charged				8208	27.00	35.20	32.60	5.20
Residue 1	1,060	1.3	52.65	11,822	.00	28.78	63.37	7.85
Residue 2	1,265	1.3	45.66	11,940	.00	12.70	77.05	10.25
Residue 3	1,200	.58	60.00	11,794	3.65	19.90	68.15	8.30
Lignite as charged				8,460	25.05	34.80	35.15	5.00
Residue 5	1,365	.84	43.50	12,240	.35	8.05	80.60	11.00
Residue 6	1,400	1.3	42.30	12,186	.00	8.40	80.50	11.10
Lignite as charged				9,940	8.55	40.55	44.25	6.65
Residue 7	1,500	1.3	50.00	12,442	.00	7.00	81.40	11.60
Residue 8	1,430	.66	53.00	12,116	.00	10.80	78.20	11.00
Residue 9	1,500	.66	53.00	12,324	.00	7.70	80.55	11.75
Residue 10	1,600	.66	52.00	12,400	.00	6.20	80.25	13.55
Lignite as charged				9,870	9.90	39.60	42.85	7.65
Residue 11	1,240	1.3	57.00	11,905	.00	14.20	75.65	10.15
Residue 12	1,380	1.0	60.00	12,512	.00	7.25	82.20	10.55

COMMENTS ON TABULATED DATA.

Regarding samples 8 and 9 it will be seen that at 900° F. nearly two hours was needed to remove the bulk of the moisture, and at that time only 1,828 cubic feet per ton of gas had been liberated as against 3,000 cubic feet of gas liberated from dry coal at the same time and temperature. It is always observed, however, that the total quantity of gas produced from the wet coal is greater when the corresponding weight of dry coal is used; but, as will be noticed, the gas produced from the wet coal contained 57.4 per cent of carbon dioxide as against 14.2 per cent from dry lignite.

Regarding samples 5 and 6, it will be noticed that at 600° little gas was driven off in two hours from the wet coal, but in the same time and at the same temperature 810 cubic feet was driven off from the dry coal. The wet coal gave 17.2 per cent of carbon dioxide as against 2.1 per cent in the dry coal.

These tests were made with lignite mine slack, and although in these series wet coal was not tested at 1,200° F., many other tests were made with wet and dry lignite at temperatures of 1,200° to 1,400° F., and the results were of a similar character, the oxides of carbon being invariably higher in gas produced from wet coal.

In general, the higher the retort temperature the larger the volume of gas, especially when the lignite is wet. As stated subsequently, 1,200° F. seems to be about the proper temperature for carbonizing lignite, and when carbonizing is done in a retort holding 400 pounds, the gas from dry lignite can nearly all be driven off at 1,200° F. in three to four hours, whereas when wet coal is used little gas is driven off in the first two hours when the temperature is at 900° F., and even at 1,200° F. five to seven hours is usually required to remove the gas.

It will thus be seen that if wet lignite is used, the time of carbonization is greatly extended, and consequently a large extra expense is incurred. At present the data as to the effect of retorting moist lignite on the ammonia and tar yields are incomplete. However, as regards the effect of temperature on the yields of gas, residue, and by-product, the experiments and tests herein reported lead the author to believe that 1,200° to 1,400° F. is the best temperature for the distillation of reasonably dry lignite.

As has already been stated, the temperature of carbonization for maximum efficiency is a matter of great importance. Of course, the lower the temperature the more economical the process becomes. There is no question but that dry lignite parts with its gases at a much lower temperature and much more rapidly than does ordinary bituminous gas coal. For the simple production of residue for briquetting purposes, if the gas were not to be saved, some means might be devised for driving off the gases economically, provided sufficient quantity were yielded with sufficient rapidity.

LOWER TEMPERATURE LIMIT OF EFFICIENT LIGNITE-GAS DISTILLATION.

For the purpose of determining the lower temperature limit of economic and efficient lignite-gas distillation, a series of tests was made, the temperature used ranging from 300° to 1,500° F., and by referring to the table on page 36 the relative yields and quality of gas obtained from the carbonization of dry lignite at 300°, 600°, 900°, and 1,500° F., may readily be seen. In this table, however, the total yield of gas shown is not as high as normal for the reason that in the tests mine waste was used instead of run-of-mine lignite, but the relative yields may be readily seen. In the tests represented by the table the gas was practically all off after the mine waste had been treated in the retort at 1,500° F. for two hours. The results given, however, should be considered along with results of tests of tar yields shown in the table on page 48, and the table on page 37, showing the results of tests to determine the lignite residues at various temperatures, and also in connection with the table on page 39, showing the results of tests to determine the lignite gas, residue, and tar yields at various temperatures. The results shown by the curves in figure 1 also should be considered here.

In all of the tests just mentioned it was not intended to procure a complete distillation of the gas, but a partial carbonization. It will be seen that although the gas yield was increased by increasing the temperature of retorting up to 1,500° F. or more, there is a corresponding loss in the tar and residue yields.

The results presented in the tables likewise show that the best temperature for the maximum tar yield appears to be about 1,200° F., with sufficient time for the complete distillation. After this temperature had been exceeded, the tar yield generally lessened, as also did the residue. Comparatively little tar was produced at a temperature less than 900° F. The results of the tests mentioned seem to be in harmony with the general results obtained with other coals by Porter and Ovitz.[a]

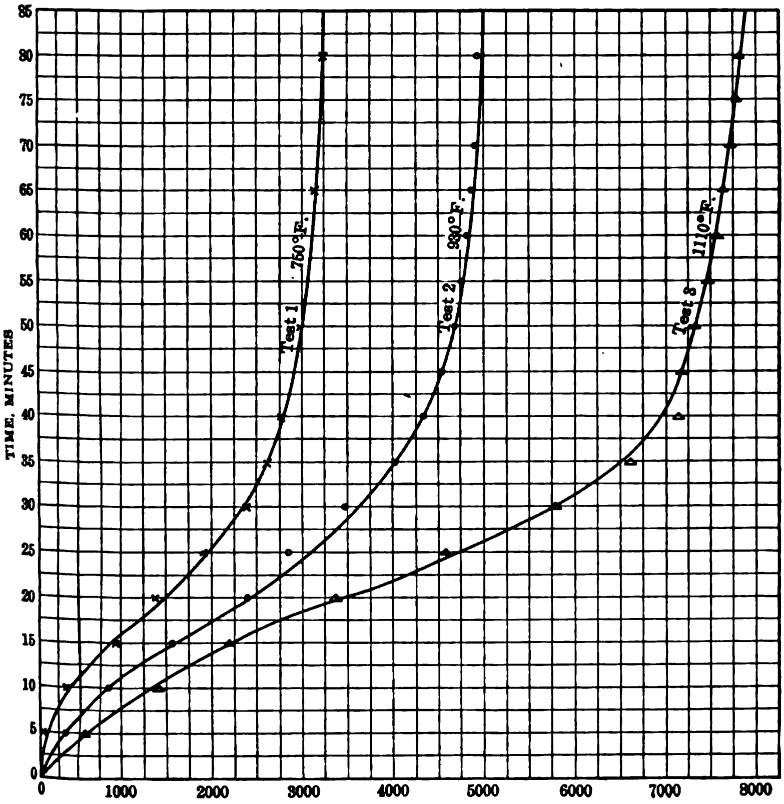

FIGURE 1.—Effect of time and temperature on lignite gas yield.

Results of retort tests of lignite[b] *to determine effect of temperature and time of retort treatment on yield of tar.*

Sample No.	Duration of test.	Temperature.	Yield of tar per ton of lignite.	Specific gravity of tar.
	Hours.	° *F.*	*Pounds.*	
1	1	900	39.26	0.9144
2	3	900	46.20	.9492
3	1	1,200	67.00	.9776
4	3	1,200	77.78	.9711
5	1	1,500	61.80	.9467
6	3	1,500	56.40	.9310

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[a] Porter, H. C., and Ovitz, F. K., The volatile matter of coal: Bull. 1, Bureau of Mines, 1910, 56 pp.
[b] Lignite mine-waste slack, containing about 20 per cent moisture.

RETORT TESTS OF BITUMINOUS COAL AND OF LIGNITE.

In order to obtain a more satisfactory basis for a comparison of the yields of gas and residue and the character of each in connection with the temperature of retorting bituminous coal and lignite under the same conditions, comparative runs in the small experimental plant were made with bituminous coking gas coal and with lignite containing a fairly high percentage of ash. Careful records were made in each run so that a comparison of the more important results could readily be made.

In making the tests the general methods employed with gas coals were followed to a large degree, in order that the results of the tests might furnish a standard for comparative purposes and also because both coals were adapted to the standard treatment.

PROCEDURE IN TESTS.

In making each of these tests 2 pounds of coal was used. The retort was so arranged that temperature readings could be taken by means of a standarized thermocouple connected with an accurate Siemens and Halske galvanometer. Temperature readings were made and gas-yield records were taken throughout each test until no more gas was driven off; the gas yields were then computed to standard temperature and pressure; the residue was cooled and drawn and the residue yield was computed. The residue was also analyzed and calorimeter determinations were made and an analysis and a calorimeter determination of the gas from each test were also made.

RESULTS OF THE TESTS.

The following table presents the results of the tests, including a statement of the composition of the two coals used and the analyses of the gas and residue. In each of the tests the gas was run directly from the hydraulic main to the gas holder in order to avoid any chance of loss in gas content.

Results of retort tests to determine comparative gas, residue, and coke yields from bituminous and lignite coals.

	Moisture.	Volatile matter.	Ash.	Fixed carbon.	Sulphur.	Heating value. per pound.	Gas.		Yield of residue.	Yield of coke.
							Gas yield per pound of coal.	Heating value per cubic foot.		
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*B.t.u.*	*Cu.ft.*	*B.t.u.*	*P. ct.*	*P. ct.*
Lignite	11.53	35.18	[a]17.20	36.09	1.44	8,675	5.08	415	55.12	....
Bituminous coal	5.90	30.15	7.50	56.45	1.40	12,947	5.35	480	....	66.60
Residue	.80	3.10	20.15	75.95	1.27	9,740	....	....	....	....
Coke	.00	.50	8.15	91.35	1.24	13,543	....	....	....	....

[a] An unusually high ash content.

Results of retort tests to determine comparative gas, residue, and coke yields from bituminous and lignite coals—Continued.

Kind of coal.	Yield of gaseous constituents.						
	Carbon dioxide.	Illuminants.	Oxygen.	Carbon monoxide.	Hydrogen.	Methane.	Nitrogen.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Lignite	13.53	3.38	0.95	20.61	38.53	19.72	3.28
Bituminous	7.20	3.10	.90	4.55	45.55	31.60	7.10

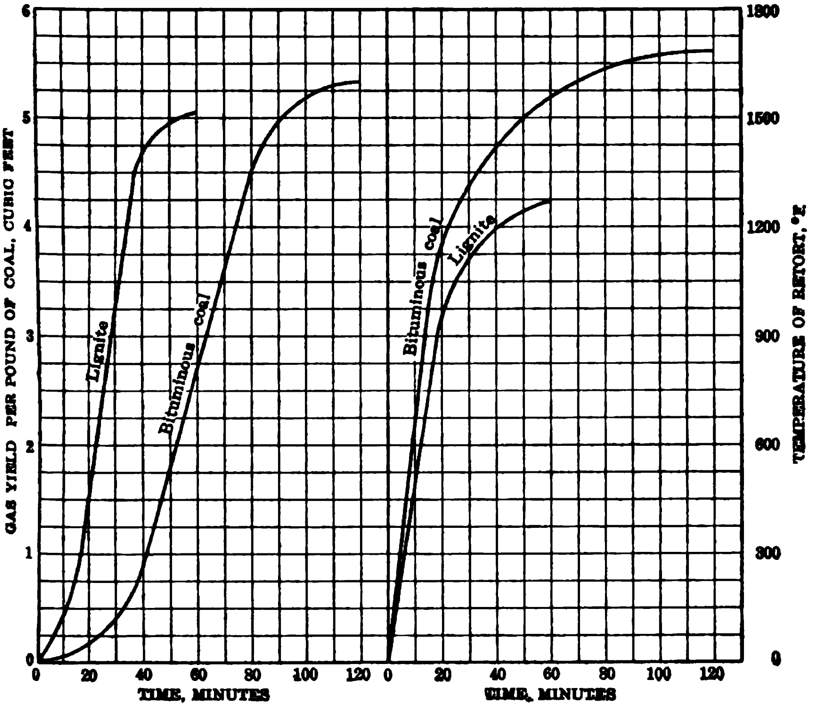

FIGURE 2.—Relative yields of gas from lignite and from bituminous coal at different temperatures and time of treatment.

The curves shown in figure 2 indicate the relative yield of gas from lignite and from bituminous coal retorted at different temperatures and at different lengths of time, the treatment being continued until the gas yield was completed.

COMMENTS ON THE RESULTS.

The curves show that the gas was removed from the lignite in about one-half the time required to remove it from the bituminous coal. The temperature required to remove the gas, it will be seen, was only 1,270° F. for lignite as against 1,665° F. for bituminous coal. The results show, in a marked manner, the ease of carbonizing lignite, and the fact that the required temperature is so much less and the necessary time of treatment only about one-half as long means, of course, a large saving in the relative cost of carbonizing, as compared with the cost of carbonizing bituminous coal.

The tests also plainly showed that the principles used in the manufacture of illuminating gas and coke may be applied successfully with proper modifications for carbonizing lignite.

The analyses of the residues showed that there was a relatively greater increase of heating value in the residue than in the coke produced from the bituminous coal, a result that would have been more marked had all of the moisture been present in the lignite and had not the sample of lignite been unusually high in ash. The yield of residue, it will also be seen, was large, much larger than might be supposed could be procured from lignite, and the coke from the bituminous coal was high in both yield and quality. The gas yield from the lignite was nearly as high as from the bituminous coal, although the time of heating and the temperature were far less.

It will also be noticed that the heating values of the crude gas were not as greatly different as were the differences in temperature and in time of production. In comparing the composition of the gases it will be readily seen that the most marked differences are found in the increased amount of carbon monoxide and carbon dioxide and in the correspondingly smaller yield of methane from the lignite. This lignite gas, however, was an excellent heating and power gas, and, as shown later, was well adapted to lighting by the use of the mantle.

Physically, the lignite residue is greatly different from the coke obtained in the carbonizing process. The coke from bituminous coal was delivered from the retort in characteristic silvery gray porous lumps, whereas the lignite was delivered from the retort in small shrunken fragments of a dull black on the outside but having a shining black surface when broken. The lignite residue is of little value in the form in which it is discharged from the retorts, but when briquetted, makes an excellent fuel, which, on account of its nonfusing quality, renders it more desirable than coke for burning in stoves and for many other purposes.

It will thus be seen that the low temperature at which dry lignite can be successfully carbonized and the rapidity with which this carbonization takes place will materially aid in reducing the cost in the use of lignite in a commercial plant.

TYPES OF CARBONIZING OVENS.

CLOSED RETORT.

Lignite could be carbonized by several methods, the choice depending on the situation of the plant and whether the gas was to be used for domestic or for power purposes, or not at all. In the discussion thus far we have considered the carbonization as having been carried on in closed retorts, such as are commonly used in city coal-gas plants. This type of ordinary horizontal retort can be used satisfactorily in the production of gas and by-products from lignite. It is the type of retort used in the experimental station and from which most of these results were obtained.

This type of retort is used extensively with bituminous gas coal for the production of coal gas for small cities, but if lignite were to be carbonized in sufficient quantity to supply the residue for a commercial briquetting plant, there would be a large volume of gas produced and a rather large number of horizontal retorts would be required. It is quite probable that in such a case a better type would be an inclined or a vertical retort, either of which can be procured in large capacities and so constructed that the cost of operation is comparatively small.

ADVANTAGES OF INCLINED AND VERTICAL RETORTS.

Lignite would seem to be especially well adapted to treatment in the inclined or in the vertical retort. Its residue does not coke or expand as does the residue from bituminous or coking coal. On the other hand, the lignite residue contracts materially and remains in separate shrunken broken fragments which can be made to discharge easily from an inclined or vertical retort.

Although the inclined or the vertical type of carbonizing plants require considerable initial outlay, the ease and low cost of their operation and the large yields of by-products and residue from them would indicate their economic adaptation to the carbonizing of lignite coal. So far as is known no trials have been made in this type of retort, but there seems to be no reason why the retorts should not be admirably adapted for the purpose. The ordinary horizontal types of by-product ovens, most of which are discharged by a mechanical pusher, would probably not be satisfactory for use with lignite for the reason that the lignite residue breaks into too small fragments to be handled mechanically by the pusher without danger of packing and sticking in the retort. Some modified form might be devised that would be satisfactory, but it is doubtful whether such a form would have any especial advantage over the vertical or inclined retorts, which are probably well suited to the treatment of lignite.

RESULTS OF USE OF BEEHIVE OVENS.

In some instances it might be desirable to briquet lignite, if the deposits were so located that there would be little or no demand for gas, at least for domestic purposes. It would then be desirable to use a carbonizing system that could be installed and operated cheaply. The beehive oven, which is extensively used for the production of coke from bituminous coal when the recovery of gas is not wanted, could doubtless be used in the carbonizing of the lignite but not with economy or satisfaction. For this reason small carbonizing ovens of modified type have been used by the writer and with lignite have given much better results than could be obtained in the beehive oven. The ovens were 6 feet wide and about 8 feet high and were supplied with air pressure and gas exhauster.

The lignite as charged into these ovens had the same moisture content as when mined, although dry or partly dry lignite would have doubtless given better results. The hot ovens first drove off the moisture and then the gas. The excessive moisture temporarily reduced the temperature of the ovens, but as soon as the moisture had been driven off the necessary oven temperature was restored. The rate of carbonization and the yields were so promising that larger modified ovens of this type will be installed, so constructed as to permit the saving of a part of the gas. It is expected that from the larger modified ovens still better results will be obtained, together with the recovery of sufficient gas to be of value for the burning of clay products, or for use in an internal-combustion engine. This special type may present possibilities for localities where there is comparatively little use for domestic gas, a condition frequently encountered near lignite deposits. For use in these ovens, as in retorts, partly air-dried lignite should be employed.

DATA OBTAINED FROM USE OF SMALL MODIFIED OVENS.

No data have yet been procured from the use of the larger modified ovens of this type. However, some information has been obtained as to the quantity and quality of residue and gas produced in a small experimental modified oven and the tables following show the results obtained.

Results of tests to determine the lignite residue resulting from operation of small modified oven.

Sample.	Yield of residue.	Analysis of residue.				
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Calorific value of residue per pound.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*B. t. u.*
A	53.3	0.00	20.40	69.53	10.07	12,590
B	49.4	.00	19.98	70.20	9.82	12,300
C	43.3	.00	10.42	80.90	8.68	13,200
D	43.3	.00	15.85	74.30	9.85	12,905
Average	47.3	.00	16.66	73.73	9.61	12,749

Analyses of gas (unpurified) from a small modified oven.

Sample No.	Illuminants.	Carbon monoxide.	Hydrogen.	Methane.	Nitrogen.	Oxygen.	Carbon dioxide.	Calculated heating value per cubic foot.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*B. t. u.*
1	0.6	6.8	3.05	11.4	50.95	3.4	23.8	166
2	.3	5.3	1.50	12.4	54.20	4.6	21.7	162
3	.7	5.6	16.10	12.8	35.10	1.0	28.7	222
4	.6	7.7	11.60	14.0	49.10	2.0	15.0	224
5	.8	7.6	13.40	16.8	18.00	1.2	42.2	263
6	.3	4.4	3.34	9.6	61.46	3.5	17.4	135
7	.6	4.0	4.65	5.55	69.00	2.8	13.4	100
Average	.56	5.90	7.66	11.79	48.26	2.63	23.20	182

The results of tests indicate that it is possible to obtain from ovens of the type used in the tests a yield of about 50 per cent lignite residue, having about 70 per cent fixed carbon and a calorific value of about 12,000 British thermal units and in addition recover by-product oven gas having a calorific value of probably at least 150 British thermal units per cubic foot.

In the recovery of this oven gas the first part is not removed, but is allowed to burn in the oven in order to bring up the temperature. In a like manner the recovery of the gas is discontinued a short time before the evolution of the gas ceases. Thus the oven temperatures are retained and a considerable recovery of gas is expected to be made in the large ovens.

VALUE AND USES OF LIGNITE GAS.

CHARACTER OF LIGNITE GAS.

From the yields of lignite gas in the tests reported in this bulletin, which represent the character of gas produced on a considerable scale and probably aggregating 1,000,000 to 2,000,000 cubic feet, it is evident that from the carbonization of lignite there can be recovered unpurified gas that will have a heating value of nearly 400 British thermal units per cubic foot, and of sufficiently good quality to render it valuable for many purposes. Furthermore, the yield of gas from partly air-dried lignite is excellent, reaching 10,000 or 11,000 cubic feet per ton. This quantity would, of course, be reduced if calculated on the basis of wet lignite.

The retorting has been done at comparatively low temperatures, thereby reducing considerably the cost of production. The gas is rather high in carbon dioxide and hydrogen, as will be seen by the analyses, but, as has already been stated, the high content of those constituents is undoubtedly due in a large degree to the moisture and air that are absorbed on account of the porous character of the lignite. Part of the moisture, however, is derived from the air in the retort and pipes, a condition unavoidable in stopping and starting an experimental plant, but such moisture would be much less proportionally if the gas were manufactured continuously in a large plant. In retorting, the oxygen from the air, present from the sources just mentioned, combines naturally with the carbon forming a larger proportion of carbon dioxide and carbon monoxide, thus leaving a relatively large proportion of nitrogen.

The gas made from lignite has been subjected not only to a large number of chemical and calorific tests, but has also been put to a great variety of practical uses. It has been burned in the ordinary manner for lighting purposes and gives a most satisfactory and brilliant light when used with the ordinary mantle burner, although it has small illuminating qualities when used in the open-tip burner. When used with a mantle it produces a clear smokeless flame that, with proper adjustments, may be easily regulated so that the light will equal that produced from the use of ordinary city gas with mantles.

A series of photometric tests of the gas used with a mantle have been made, and show excellent results. The gas seems sufficiently free from sulphur and other objectionable impurities to permit its use without complete purification. The cost of the gas supplied for domestic purposes would thus be materially reduced. Of course the gas would be subjected to the usual water scrubbing.

It is true that the gas is rather high in carbon-dioxide content, but if the gas were produced as a by-product in the manufacture of briquets from lignite, it could be made at such a low cost that if distributed unpurified it could be sold at a correspondingly low price and used with mantles for lighting and for cooking without the necessity of treatment for the removal of carbon dioxide. The gas could be purified in the usual manner and enriched, but the wiser way would seem to be to sell the gas at low enough price so that purification would not be necessary.

The author has used the gas without purification rather extensively for lighting, heating, and experimental purposes. Purification, however, could be done by the methods usually employed for purifying ordinary coal gas, and if the gas were thus purified, the composition and heating power would be considerably modified. The heating value developed would probably be increased to 450 British thermal units. The gas could then be further enriched if desired.

The lignite gas is naturally what is known as a "dry" gas and when delivered from the holder is almost free from tar and other matter that in ordinary city gas often causes trouble through condensation and clogging. Its freedom from such constituents would be a material aid in the practical distribution and use of lignite gas, especially in cold climates. The most severe and continued tests have been given lignite gas to determine the condensation produced when it is carried in slightly protected pipes during cold weather. In the tests no trouble was experienced from condensation.

The gas has been successfully used not only for lighting, cooking, heating, etc., but also in a small way for generating power. It has given uniformly excellent satisfaction, with unexpectedly high efficiency.

USE OF LIGNITE GAS FOR POWER PRODUCTION.

The use of lignite gas either from retort ovens or modified ovens presents many commercially attractive features. Although the power tests have not as yet been carried very far, enough has been done to prove that the gas can be used with entire satisfaction for power in gas engines. Several tests have been run with modified gasoline or gas engines at the mining substation and at the school of mines. At the latter the tests were made in comparison with standard city gas, and the lignite gas was found especially satisfactory, developing relatively high efficiency.

There is little doubt that lignite gas can be successfully employed for power purposes, and that power can be produced at such a low figure as to exert a marked influence in the development in the Western lignite area of a variety of industries dependent on cheap and abundant power, which, with the establishing of large by-product plants, may become a close rival of hydroelectric power.

Because of the ease with which the gas is produced, the low cost of the original lignite, and the value of the residue when briquetted, the gas should have a large commercial value for lighting, heating, and power purposes in many districts, especially in view of the low price for which it could be sold if manufactured as a by-product in a plant used also to produce briquets from lignite residue.

YIELD OF AMMONIA AND TAR FROM LIGNITE DISTILLATION.

Tests to determine the yield of ammonia from lignite indicated a yield as large as could be expected. This by-product in the form of ammonium sulphate is of considerable commercial value and is used in many ways, especially as a fertilizer. The author has not done a large amount of work on this problem, but sufficient determinations have been made to show an average yield of approximately 17.4 pounds of ammonium sulphate per ton of dried coal, or about 25 pounds per ton of briquets. The by-product is thus of sufficient value to be worthy of careful consideration because if saved in a large plant it would return considerable revenue and reduce the final cost of briquetting.

By reference to the table showing tar yields at different temperatures (p. 39) it will be seen that at temperatures of 900° to 1,500° F. approximately 50 pounds of tar can be recovered on an average from the carbonization of 1 ton of partly air-dried lignite. The exact quantity will fluctuate with the character of the lignite, the temperature of distillation, and the percentage of moisture present in the lignite. The maximum yield seems to be obtained at approximately 1,200° F. At a higher temperature it is quite evident that destructive distillation of the tar begins, thereby reducing the tar yield. The destructive distillation also causes an increased gas yield at higher temperatures, seemingly due to the breaking up of the hydrocarbons of the tar.

The table following gives the percentage of tar in the lignite used in nine tests:

Tar yields in retort tests of lignites.[a]

Sample No.	Quantity of tar per ton of lignite as charged.	Proportion of tar in lignite.	Sample No.	Quantity of tar per ton of lignite as charged.	Proportion of tar in lignite.
	Pounds.	*Per cent.*		*Pounds.*	*Per cent.*
1	26.00	1.30	7	39.26	1.96
2	27.00	1.35	8	46.20	2.31
3	77.78	3.89	9	55.00	2.75
4	56.40	2.82			
5	61.80	3.09	Average	50.72	2.54
6	67.00	3.35			

[a] The lignite was partly dried, containing 8 to 27 per cent moisture.

Variations in temperature affect the character of the tar, its specific gravity ranging from approximately 0.92 to 0.97. Under ordinary conditions the tar is a thin fluid of a peculiar odor and an oily character. The tar seems to be high in paraffin ingredients and in lignite oils, and seems to be especially well adapted for use as a wood filler, many large and small scale tests having been made of such use of the tar without further treatment. For this and other purposes it should be of considerable commercial value.

DERIVATION OF OIL FROM LIGNITE TAR.

Lignite tar is not in its natural condition adapted to briquetting purposes, but by special methods of treatment that are being developed by the writer it seems entirely probable that a large proportion of lignite tar may be used in connection with other material as an ingredient of the binder for briquetting the lignite residue, thus reducing considerably the cost of the briquet binder.

As has already been stated, the tar recovered from lignite carbonization, under proper conditions, shows an oily and paraffin character and remains under normal temperature in a free fluid condition.

Work has been begun under the direction of the writer for the recovery of several by-products from this lignite tar, and it has been found that an appreciable yield of heavy oil may be derived from the proper treatment of lignite tar that has been recovered at the proper carbonizing temperature.

As a by-product in the manufacture of lignite-residue briquets, it would appear from the work thus far done that the oil would amount to about 2 gallons for each ton of briquets produced. The flash point of the oil seems to vary between 120° and 185° F., the exact temperature depending on the conditions of carbonization and distillation. The oil undoubtedly aids in keeping the heavier and thicker pitch-forming hydrocarbons in solution in raw lignite tar.

The oil should have considerable commercial value. It could probably be used to advantage in internal-combustion engines adapted to the use of heavy oils, especially as the oil does not appear to deposit any troublesome tarry matter. A similar use of lignite oil is suggested by Allen.[a]

It will thus be seen that the lignite tar can undoubtedly be made of considerable commercial value in a large by-product plant by utilizing it in any of the various ways suggested.

LIGNITE-BRIQUETTING EXPERIMENTS.

As already mentioned, the process developed under supervision of the author for the successful manufacture of briquets from lignite is intimately associated with the production of gas; and according to this system a complete briquetting plant would also include a simple gas plant or at least the carbonizing part. Consequently, the discussion of the manufacture of gas from lignite has preceded a consideration of the subject of briquetting.

DETAILS OF PROCESS SHOWN TO BE ESSENTIAL.

The process of lignite briquetting that has been evolved at the school of mines of the University of North Dakota and at the mining substation depends on the concentration of the raw lignite into a fuel of relatively high heating value, and of sufficient value to be shipped for some distance for domestic and other use.

Such concentration depends on, first, the removal of the moisture, second, the expulsion and saving of the volatile gas, and third, the binding together of the concentrated residue into strong and durable briquets of suitable size. As the coal is removed from the mine it contains a high proportion of moisture, usually more than 30 per cent; that is, about one-third of every ton of raw lignite as mined is water. The moisture content is largely responsible for the difficulty in the successful introduction of lignite except in the immediate vicinity of the mines.

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[a] Allen, I. C., Heavy oil and fuel for internal-combustion engines: Technical Paper 37, Bureau of Mines, 1913, 36 pp.

The cost of shipping for long distances fuel containing so much water is excessive. In addition, the heating value of the coal is reduced by the high proportion of water present. On standing, a part of the water evaporates from the coal, but the evaporation tends to reduce the lumps to slack, causing thereby a large amount of waste. In converting the raw lignite into the condensed briquets, the first step is the removal of the water in a manner least harmful to the lignite.

METHOD OF DRYING THE LIGNITE.

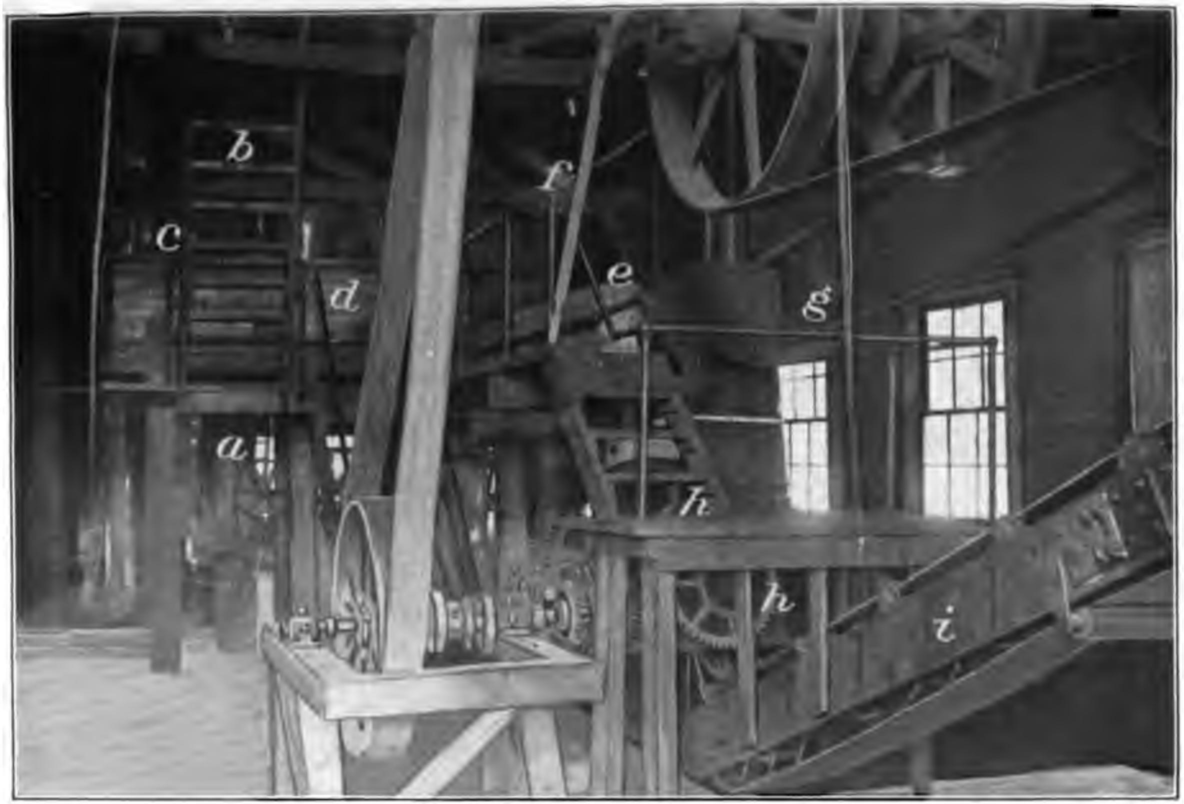
In the experimental plant, if the gas is to be saved especially for domestic lighting or heating, the drying of the lignite is done first by means of a rotary drier. The large lumps as removed from the mine are crushed to about the size of an egg. They are then run through the drier, which removes 75 to 90 per cent of the moisture. There are a variety of types of driers that can be used for this purpose, but the style employed at the experimental plant consists of a sheet-steel cylinder attached to a revolving shaft which serves to feed and mix the coal while the cylinder is slowly revolving.

Beneath the cylinder is a small fire box so arranged that it will gently heat the revolving cylinder. The whole machinery is inclosed in brickwork. Slack coal is used for firing, and only a small amount is required per ton of raw coal dried. The power per ton for driving the drier is also small, and the operation is efficient.

After the coal has been sufficiently dried it is conveyed to the gas-retorting room and is treated in the retort after the manner already explained. This process is usually completed in about four hours. At the end of this time the retort is discharged and the remaining coal residue conveyed to a brick bin, where it is quenched with a spray of water.

BRIQUETTING PLANT OF NORTH DAKOTA SCHOOL OF MINES.

The experimental briquetting plant (Pl. III) is continuous, with a capacity of 15 to 20 tons per 10 hours. In this plant the carbonized residue goes first to a disintegrator, which breaks all lumps of residue to a ¼-inch size and finer. The broken residue is then conveyed to a set of rolls which reduce it to the proper size for briquetting. It is then lifted by elevator (*a*, Pl. III) to a bin (*b*, Pl. III), from which it passes through an automatic feeder (*c*, Pl. III) which gives the correct proportion of residue to binding material.



PART OF LIGNITE-BRIQUETTING PLANT AT SUBSTATION AT HEBRON, N. DAK.

a, Elevator; *b*, ground-residue bin; *c*, measuring and feeding machine; *d*, preheater and conveyor; *e*, mixer for binders and lignite; *f*, binder tanks; *g*, cooler to temper mixture; *h*, *h*, briquetting press; *i*, briquet conveyor, leading to storage bins.

At this point an automatic feeder delivers also the proper amount of ground screenings, or low-grade flour, 1 to 2 per cent generally being used. The mixture is then delivered to a preheater and conveyor (*d*, Pl. III) which conveys and mixes the dry material and at the same time brings it to a temperature of about 100° F.; thence it is delivered into the mixer (*e*, Pl. III). At this point the binding pitch is introduced through a rotary meter, by means of which the exact amount of pitch binder desired may be used. Most of the pitch used has a melting point of 145° F.

The pitch is melted in a steam-heated tank (*f*, Pl. III), from which it flows by gravity to the meter. It is then sprayed and blended with steam in the mixer. The mixer is steam-jacketed and so designed that it thoroughly mixes the binding material and the lignite residue, at the same time moving the mixture forward and delivering it at exactly the proper speed for the briquetting press. On its way to the briquetting press the mixture is carefully cooled to the proper temperature by a special device (*g*, Pl. III) which can be regulated to meet the changes in atmospheric temperature. The mixture then passes through the press (*h*, Pl. III) and the briquets are delivered to a cooling belt (*i*, Pl. III) which conveys them to storage bins.

The plant is complete and no hand work is done from the time the residue is delivered to the crusher. All of the machinery is carefully timed so that every part operates at the proper speed and delivers exactly the right proportion of material. Considerable skill is required in the operation of the plant to keep the adjustment exactly right, but the plant has been so carefully constructed that it operates uniformly and with comparatively little attention.

There are numerous details of mixing, cooling, etc., that can be properly understood and controlled only by experience. Conditions vary greatly with the kind and character of the binding material used.

BRIQUETTING PRESS USED.

The press that is used at the experimental plant is of the rotary type. It was built to order and is capable of producing 2 tons of briquets per hour. Careful consideration indicated that for the lignite material in the form being used the simplest type of rotary press would probably be the most satisfactory; moreover the simplest and most easily operated machine and the one requiring the least power seemed most desirable. The type of press shown in Plate IV, *A*, has proved satisfactory.

There are several varieties of briquetting machines. They are in the main, however, of two kinds, namely, the rotary and the plunger types. The plunger machines are made in either low or high pressure styles, and have been rather extensively used in

Europe. With certain varieties of coal and certain types of binders such presses have been satisfactory, but the rotary machine seemed well adapted to the purposes of the experimental plant and was selected for the work on the lignite.

The machine used is extremely simple in its design and operation. The material to be briquetted is fed between two rolls, the surfaces of which are covered with pillow-shaped pockets, half of a pocket being on the front roll and half on the rear roll. The rolls are so geared that the two halves of each pocket exactly match as the rolls revolve. The lignite mixture is caught between the rolls, pressed into the pockets, and formed into firm dense briquets, which, as the rolls revolve, are discharged to a belt conveyor, by which they are carried to the storage bins. The experimental press produces a briquet weighing 2¼ ounces, and when producing 2 tons of briquets per hour requires about 8 horsepower.

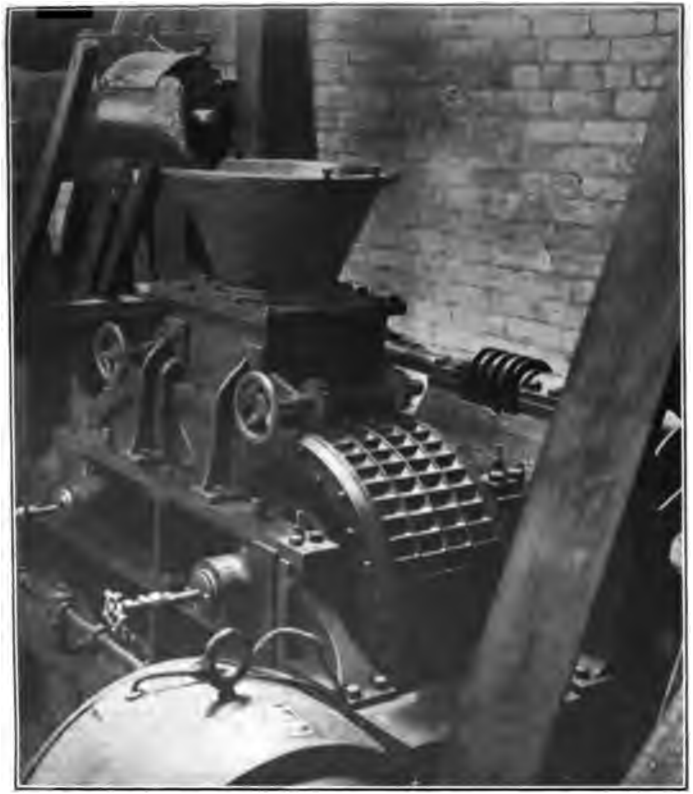
Some presses of this type have a capacity of 10 to 20 tons per hour of finished briquets, but the operation is in every way identical.

CHARACTER OF BRIQUETS MADE BY DIFFERENT PROCESSES.

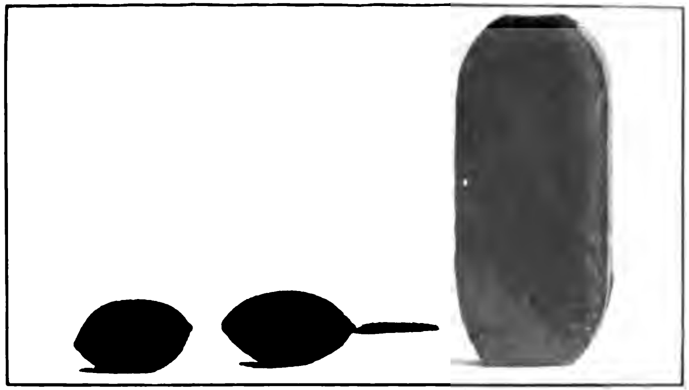
Briquetted fuels have been extensively used in Germany and in other parts of Europe, where a variety of methods of manufacturing have been employed, with varying degrees of success. With certain European coals briquet blocks have been produced without a binder, whereas with other coals lime, sugar wastes, starch, pitch, and other binding materials have been employed. Numerous attempts have been made in this country to briquet lignite without a binder merely by excessive pressure, but the plan has proved unsatisfactory. By such a process the expense for power and operation nearly equals the cost of the binder. Moreover, no satisfactory briquets of American lignites have been produced on a commercial scale without a binder. It has therefore been generally conceded that in America the best briquets are produced by the use of some binding material.

It is true that in some instances good-looking raw-lignite briquets have been obtained in a small way by the use of high pressure and without a binder. However, such briquets have not really been satisfactory. Some have appeared all right until they were exposed to the weather or to furnace heat, when they would disintegrate. Briquets are not made for looks but for fuel purposes. They must, therefore, be capable of successfully withstanding rough handling, severe weathering, and hard furnace use.

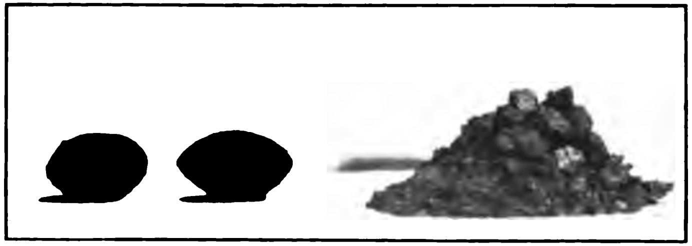
Most raw-lignite briquets—that is, those made simply from partly air-dried lignite either with or without a binder—look satisfactory when they have not been subjected to the severe tests required for



A. BRIQUETTING PRESS, SPECIALLY ARRANGED FOR EXPERIMENTAL WORK OF SCHOOL OF MINES, UNIVERSITY OF NORTH DAKOTA.



B. BRIQUETS BEFORE HEATING. AT LEFT, STANDARD LIGNITE-RESIDUE BRIQUETS; AT RIGHT, RAW-LIGNITE BRIQUET.



C. BRIQUETS SHOWN IN *B*, AFTER HEATING. LIGNITE-RESIDUE BRIQUETS IN GOOD CONDITION; RAW-LIGNITE BRIQUET EXPANDED AND DISINTEGRATED.

a commercial fuel. Some of these briquets will stand fairly well a short period of weathering, but most of them, especially those that have been made from air-dried lignite under heavy pressure and without a binder, become brittle and are easily broken even by moderate handling after having been exposed for a short time to atmospheric conditions and furnace heat.

Briquets produced from air-dried lignite from which only the water has been removed will not stand successfully ordinary furnace conditions, particularly if the briquets are made without a binder. The briquets made of the dry lignite contain all of the light volatile gases of the original lignite lumps. When briquets of this character are heated in a furnace until they begin to glow, the large quantity of light gas contained in the partly dried lignite is rapidly forced out of the briquet, causing it to either crumble in the furnace or become so fragile that a mere touch of the poker will make it fall to pieces. The dry lignite particles that have not had an opportunity to burn then begin to fall through the grate, and much material drops unburned into the ash pit. In fact, such briquets are not commercially as practical as lump lignite and, moreover, there has been considerable cost added to them in the process of drying, crushing, and briquetting.

It is true that such dry lignite briquets may on test show a calorific value as high as 9,000 or 10,000 British thermal units, but when actually burned in the furnaces this calorific value is nowhere near realized because of the disintegration mentioned. Consequently the briquetting of air-dried lignite whether without or with a binder does not promise a satisfactory commercial product.

Many efforts have been made to obtain a form of air-dried briquet that would meet the requirements of a commercial fuel, but none has suceeded in a commercial way so far as the use of Western lignites is concerned. In the briquetting of German lignites, the conditions are entirely different from those encountered in connection with most Western lignites. After much investigation and many hundreds of tests, the writer has been convinced that the most satisfactory, if not the only successful, method of briquetting lignite, is to carbonize the raw lignite so as to remove at least a large proportion of the volatile gases as well as the moisture.

The residue, as shown previously, has a greatly increased heat value, and, relieved of its excess of light gases, becomes an excellent material for briquetting. Briquets from this residue when produced as described above stand handling, weathering, and severe furnace tests with a high degree of satisfaction.

BURNING TESTS OF BRIQUETS MADE IN EXPERIMENTAL PLANT.

Plate IV, *B*, shows a large briquet made of dried lignite and two small briquets made from lignite residue by the process previously described. These two briquets were placed side by side on a fire-clay slab and introduced into a muffle furnace which was heated to redness. In a few moments the briquets were heated to the point of ignition. The small briquets burned with little flame and retained their form perfectly. The large briquet soon began to crumble, and, although unburned, soon disintegrated so far as to leave only the mass of lignite particles shown in Plate IV, *C*.

TYPES OF BINDERS USED.

Many different binders have been employed both in Government and in private tests but the one most widely used and most generally satisfactory is some form of pitch, usually what is called a rather hard pitch. Best results at the experimental plant have been procured with a pitch having a melting point of about 145° F. There are many advantages in such a binder. It is readily obtained in large quantities from coal-gas plants and from by-product coke ovens. It is reasonably cheap and is free from ash, has excellent heating qualities, and as a binder produces a strong and waterproof product. For these reasons in most of the briquetting work herein reported some form or combination of pitch binders has been used, but many other binders, such as flour, starch, gypsum, and various combination binders, have also been used. Up to the present time the best results have been achieved, however, by using a small amount of pitch as a binder base and mixing with it a small percentage of some of the other materials mentioned. Several hundred tests have been run with different binders in different proportions and under varying conditions. Probably the best and cheapest lignite-residue briquets have been made with a mixture of 5 or 6 per cent pitch blended with about 5 per cent bituminous coal dust and 1 to 2 per cent of flour or fine ground screenings from grain.

In the process of gas manufacture the author has found that about 50 pounds of tar is obtained from carbonizing 1 ton of dry lignite, or, in other words, there would be produced by the experimental methods of manufacture over 50 pounds of tar for every ton of lignite briquets produced, the exact quantity depending upon the degree of carbonization. By a simple process on which the writer is now working, the tar can probably be utilized for a considerable part of the binder material, so that probably not more than 4 per cent of pitch in addition to that derived from the lignite will be required. Or, if the lignite tar is more valuable than ordinary pitch, as now seems probable on account of its peculiar composition, it may be sold at sufficiently high price to go a considerable way in reducing the cost of the other binders required in briquetting.

Attention has already been called to the desirability of using the gas in connection with the briquetting, and to the revenue that may be derived for the plant by a combination of gas and briquetting plants, but in addition, as has already been mentioned, there is a considerable quantity of ammonium sulphate formed (about 25 pounds per ton of briquets), and this by-product has a ready market. Thus, if the various by-products are saved and the revenue derived from them is applied to the manufacture of the briquets, the cost may be materially reduced. In a large commercial plant the saving of a few cents per ton will be sufficient to net a good profit.

The briquets now being produced regularly and in considerable quantities at the mining substation are first-class in every respect. They are strong, hard, durable, and will stand weathering excellently and burn with entire satisfaction in almost any type of stove or furnace. They have been tested in a great variety of ways and have given good results.

ABRASION AND CRUSHING TESTS OF BRIQUETS.

In order to determine how well lignite briquets would stand such necessary handling as loading, shipping, and shoveling, a large number of comparative tests were made with the briquets and with the best grade of lump soft coal. Abrasive, drop, and crushing tests were included. The abrasive tests were made in a machine having two rotating cylinders on the same shaft. In one cylinder was placed a weighed quantity of lignite briquets and in the other a weighed quantity of standard coal of the same size; the cylinders were then rotated for the same period and at the same speed. At the end of the test the remaining lumps were removed, and the fine as well as the broken parts of each less than one-half inch in size were weighed and the percentage of abraded material calculated. The table following gives the results of the tests.

Results of comparative abrasion and crushing tests of various kinds of coal and of lignite briquets.[a]

Sample No.	Kind of coal.	Proportion larger than 1-inch size remaining after abrasive tests.	Crushing strength per square inch.
		Per cent.	*Pounds.*
1	Anthracite	98.50	3,950
2	Kentucky lump	93.43	1,970
3	Youghiogheny	81.20	3,680
4	do	86.65	1,510
5	Pocahontas	75.75	1,556
6	Lignite briquets	99.60	1,810
7	do	97.75	1,370
8	do	99.38	1,530
9	do	99.23	1,825

[a] Results represent averages of three tests.

The table indicates that lignite briquets withstood abrasion better than any of the coals tested, including both anthracite and bituminous varieties. The briquets would therefore stand handling remarkably well and the loss in dust would not be large.

In the crushing tests it was not supposed that the briquets would give nearly as high results as would standard coal. It will be seen, however, that the briquets were stronger than the Pocahontas coal and averaged nearly as strong as Youghiogheny coal. The results of both the crushing and the abrasion tests were remarkably satisfactory.

DROP TESTS.

Drop tests were also made in a specially designed drop-test box from which a definite weight of briquets and standard coal were alternately dropped from the same height. The percentage of broken lumps from each test was determined. Comparative breaking tests were also made by briskly striking together the briquet and the coal used for comparison. In nearly all the tests soft-coal lumps were readily broken without injury to the briquets. The breaking and drop tests indicated that lignite briquets are stronger than many bituminous coals.

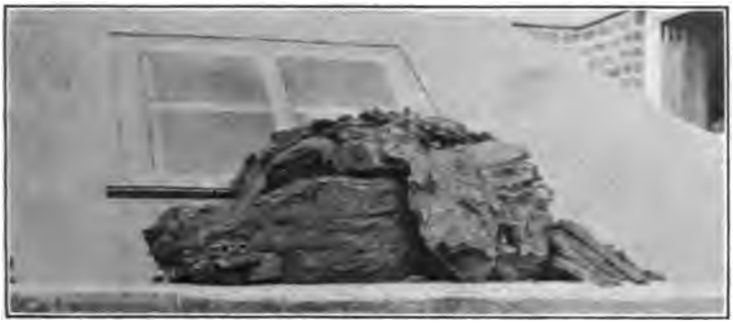
It will thus be seen, from the results of the series of tests outlined, that the briquets produced from lignite residue have excellent physical qualities and will unquestionably stand shipment and handling satisfactorily. The briquets can be considered a reasonably clean and satisfactory fuel to handle.

WEATHERING TESTS.

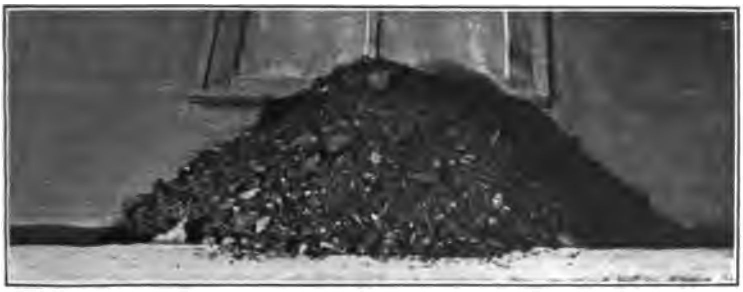
In order to determine the ability of the lignite-residue briquets to withstand weathering, a number of severe tests were made. In one set of tests a pile of the briquets was exposed on the roof of a building for one year. There the briquets were compelled to withstand all the changing climatic conditions, such as wind, heat, rain, and frost. At the end of one year the briquets were still in fairly good condition and could be used for fuel purposes. They showed only slight surface effects.

In another test half a carload lying on the ground was exposed to the weather for six months, with hardly any perceptible weathering effect. Such results show the remarkable difference in the action of weather on briquets and on the raw lignite. Lignite as mined quickly slacks into small pieces or dust on exposure to the atmosphere.

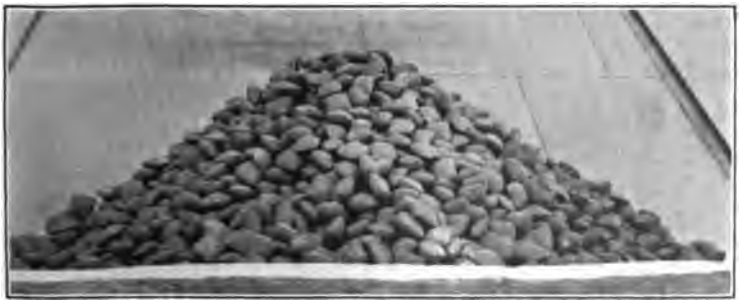
Plate V, *A*, shows a lump of freshly exposed lignite and Plate V, *B*, shows the slack produced after similar lumps had been allowed to stand a short time in the air. Plate V, *C*, shows a pile of briquets that had been exposed to the weather for six months without appre-



A. LIGNITE LUMP, AS MARKETED.



B. STACK OF LIGNITE LUMPS AFTER EXPOSURE TO WEATHER.



C. STANDARD LIGNITE-RESIDUE BRIQUETS AFTER EXPOSURE TO WEATHER FOR SIX MONTHS.

ciable effect. It will thus be seen that briquets made from carbonized lignite residue are well qualified to stand considerable exposure without material deterioration, and that the value of the process is sufficient to warrant a considerable briquetting expense on this account, to say nothing of the increased heating and other values.

The briquets stand in the furnace during the complete process of combustion without crumbling, and, as already mentioned, this quality is important and seemingly can not be obtained by any process of briquetting the simple dry lignite. Briquets made from carbonized lignite residue, however, stand through the whole period of burning remarkably well. They are frequently seen in perfect form until all of the fixed carbon has been burned. If, then, the ash is touched with a rod, it falls to a powder, showing practically no unconsumed carbon.

This property of the briquets of withstanding the effect of intense furnace heat without disintegration is one of great practical commercial value, and the fact that the ash burns clear of carbon permits a marked saving over the ash loss of bituminous and anthracite coal as ordinarily burned, for in the ash of these coals it is well known that there is a considerable proportion of unconsumed fixed carbon. Consequently, it is possible for carbonized lignite briquets, even of a lower calorific value than anthracite or soft coal, to equal or surpass such coals in actual heating results.

RÉSUMÉ OF ADVANTAGES OF BRIQUETTING.

The chief advantages to be gained in briquetting carbonized lignite as outlined are the large gain in heat value, the prevention of slacking so characteristic of this coal, the holding together of the mass during combustion, the prevention of matting in the fire box, free burning, uniformity in size, cleanliness in handling, and decrease in the losses. In addition, briquets can be used to better advantage in a variety of stoves and may be kept under more perfect control than the ordinary form of lignite. But the greatest advantages are the increased heating power and the fact that the lignite is put into a form which will stand weathering, handling, and burning without disintegration.

The briquets have many advantages over ordinary coal on account of their uniformity of size and shape, which make them well adapted to ordinary use, as they are free from the extra small and extra large fragments so often found in lump coal. There is comparatively little loss through the grate bars; they burn to an ash, in which practically all of the fuel has been consumed. Anthracite coal leaves a considerable amount of clinkers containing more or less black imperfectly burned fuel or carbonaceous matter. The complete combustion of lignite briquets is greatly in their favor as regards economy.

CALORIFIC DETERMINATIONS.

It will be seen that briquetting the lignite raised its heating power about 70 per cent and gave a calorimeter value of approximately eleven-thirteenths to twelve-thirteenths the heating value of anthracite coal. If lignite low in ash is thoroughly carbonized and the resulting residue briquetted, the briquets will show by chemical analyses an approximate composition not greatly below anthracite coal. Chemical analyses of such briquets as compared with those of raw lignite and anthracite coal are shown by the following table:

Chemical analyses and calorific values of anthracite coal, lignite, and lignite briquets.

	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Heating value.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*B. t. u.*
Lignite as mined	35.01	25.11	34.67	5.21	7,000 to 7,800
Lignite briquets	0 to 6	2 to 8	72 to 82	10 to 16	11,500 to 12,000
Anthracite	1 to 5	2 to 6	78 to 92	10 to 15	12,000 to 13,500

The lignite briquets represented in the table were made from a good grade of lignite, low in ash, which had undergone relatively complete carbonization. It may be said, however, that in order to procure results as satisfactory care must be exercised in selecting lignite of low ash content, for in the carbonization the ash is concentrated along with the fixed carbon in the residue. If, therefore, the ash content in the raw lignite is high, it will be greatly increased in the residue, and may be so high in an impure lignite as to reduce materially the calorific value and efficiency of the briquets. Therefore the selection of low-ash lignite for briquetting purposes is of great importance.

If, however, raw lignite having a high ash content is to be briquetted, the results of the tests herein reported indicate the desirability of stopping the carbonization before it has been fully completed. By this method the light hydrocarbons are driven off, but the heavier hydrocarbons remain behind, increasing the yield of residue considerably and reducing the relative proportion of ash. The residue gives a briquet that burns with considerable flame, but it has high heat value and is, withal, an excellent fuel for general use.

A large proportion of the briquets produced at the experimental station have been made from the partly carbonized residue, and all of the tests reported in the following pages were made with this type of briquet. It contains slightly less fixed carbon and ash than does the briquet made of completely carbonized lignite, and contains slightly more volatile matter. The calorific value, however, remains nearly the same.

The results presented in the following table may be taken as representative of the bulk of semicarbonized lignite briquets, amounting to several hundreds of tons, produced at the experimental substation, and it may be said that briquets of the quality indicated are readily produced from most of the lignite coals. The table covers tests of briquets made from Montana, Colorado, Texas, and a large number of North Dakota lignites.

Results of tests of semicarbonized lignite briquets.

Sample No.	Calorific value, per pound.	Chemical analyses.			
		Moisture.	Volatile matter.	Fixed carbon.	Ash.
	B.t.u.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	11,642	3.85	19.08	66.82	15.25
2	12,137	4.15	17.65	64.10	14.10
3		5.43	18.18	62.56	13.83
4		4.83	15.25	64.10	15.82
5		5.55	14.45	65.55	14.45
6		5.80	14.87	64.48	14.85
7		5.72	15.48	63.08	15.72
8	11,557	6.50	22.10	59.30	12.10
9		6.65	17.77	62.80	12.78
10		6.30	16.21	64.39	13.10
11		6.05	15.21	64.69	14.05
12	11,981	3.90	15.83	64.77	15.50
13	11,669	3.57	16.23	65.03	15.17
14		5.97	16.25	63.46	14.32
15		5.38	16.70	63.82	14.10
16		4.97	14.44	64.96	15.63
17		4.35	12.21	67.49	15.95
18	11,926	6.18	11.35	68.13	14.34
19		4.80	14.09	66.01	15.10
20		5.65	16.27	63.80	14.28
21		5.12	16.76	63.92	14.20
22		4.78	14.66	65.90	14.66
23		5.08	17.04	63.65	14.23
24	11,599	5.85	12.20	67.38	14.57
25	12,024	4.83	12.22	67.50	15.45
Average.	11,692	5.25	15.70	64.51	14.54

COMPARATIVE BURNING TESTS OF BRIQUETS.

In many practical burning tests the lignite briquets have been compared with anthracite coal and the best grades of Youghiogheny soft coal. The lignite briquets have been used under boilers and have proved an excellent and economical steaming fuel. They have been used in hot-air and hot-water heating plants with excellent results. They make a pleasing grate fire, much easier to control than one made of either hard or soft coal. In the kitchen range they have proved particularly satisfactory; they are easily kindled and produce a high heat with a slight flame which is free from soot, leaves the stove and lids clean, and produces an excellent fire for cooking and baking. They hold the heat well, last over night, and can be controlled readily by operating the grates and drafts. They have burned with excellent results in the direct-draft heating stove and self-feeding base-burner hard-coal stove.

EQUIPMENT USED IN TESTS.

In order to determine the practical value of lignite briquets as compared with anthracite coal, and as compared with raw lignite, a number of carefully conducted stove tests were made. The direct-draft stove was one of special design. It included a reservoir for evaporative purposes, which could be closed by a sliding jacket to prevent any modification of results from the atmosphere of the room. The hard-coal stove used was a standard type of self-feeder of medium size and small feed diameter. In the selection of the stove and in the conducting of the tests the ruling consideration was the objects to be obtained, which were to determine the total heat produced by briquets and the length of time of their burning, whether they would feed satisfactorily from a self-feeding stove in which the magazine was of small diameter and whether the fire could be easily controlled and kept, and to throw light on other problems associated with the practical use of the briquets in ordinary stoves. These stoves were set up in a small room in the basement of the school of mines building. The size was about that of an ordinary house stove. The room was an inside one, well protected from changes in temperature.

Special control of drafts and pipes was provided, and arrangements were made so that the temperature and flow of air through the stove and pipe could be determined at frequent intervals. The temperature of the room was uniform in all the tests, and records were made every 15 minutes during the tests. The briquets and anthracite coal were burned under exactly the same conditions and the same quantity of each fuel was used in each test.

TABULATED RESULTS OF TESTS.

Averaged results of the tests were as follows:

Results of heating-stove tests.[a]

Item.	Anthracite coal.	Lignite briquets.
Coal fired .... pounds..	45	45
Time fire lasted .... hours..	19	25
Unburned coal on grate .... pounds..	6.00	0.125
Ash in pan .... do....	7.438	8.063
Fixed carbon in ash .... per cent..	43.55	3.65
Fixed carbon in ash .... pounds..	3.239	.294
Gross heating value .... per cent..	100	126.1
Heating value, all material passing through grate assumed to be completely burned .... per cent..	100	109.7

[a] The results are averages of all the tests.

Results of evaporation tests.[a]

Item.	Anthracite coal.	Lignite briquets.
Coal fired .... pounds..	15	15
Time fire lasted .... hours..	5¾	5¼
Evaporation at stove top .... pounds..	13.875	16.813
Total evaporation from and at 212° F .... do....	16.156	19.532
Unburned coal on grate .... do....	2.875	0.125
Ash in pan .... do....	4.563	2.500
Gross heating value .... per cent..	100	104.9
Heating value considering all fuel including that left on grate to have burned, per cent	133.6	132.1

[a] The results are averages of all the tests.

Results of fuel tests, showing comparisons of available heat and calorific values.

Name of fuel.	Available heat.			Calorific value.		
	Degree-hours per pound.[a]	Percentage of available heat of anthracite taken as 100.	Percentage of available heat of briquets taken as 100.	Heating value per pound.	Percentage of calorific value of anthracite taken as 100.	Percentage of calorific value of briquets taken as 100.
		Per cent.	*Per cent.*	*B. t. u.*	*Per cent.*	*Per cent.*
Anthracite	14.76	100.00	115.04	13,500	100.00	117.39
Lignite briquets	12.83	86.25	100.00	11,500	85.18	100.00
Lignite containing 20 per cent moisture	5.75	38.89	44.74	9,000	66.66	78.26
Lignite containing 30 per cent moisture	4.88	33.06	38.04	7,800	57.78	67.83

[a] Rise in temperature in degrees centigrade times the time in hours.

The results of the tests are also indicated in the curves shown in figures 3, 4, and 5.

COMMENTS ON THE RESULTS.

The tests showed that the briquets did not require as much draft as did the anthracite coal.

The excellent showing made in the actual stove tests was due in a large measure to the fact that the lignite briquets, although having only about twelve-thirteenths the calorific value of anthracite when burned in a stove were completely consumed, leaving no unburned carbon on the grates or in the ash as did the anthracite. This is clearly seen by comparing the carbon in the anthracite ash with that in the lignite-briquet ash. It will be seen that the anthracite ash with its little fragments of carbonaceous partly burned clinker contained about 13 times as much unburned carbon as did the lignite-briquet ash.

The table last preceding indicates the low efficiency obtained in the actual burning of lignite as ordinarily mined and marketed, a condition in which it is shown to have an efficiency less than one-third that of anthracite and only a little more than one-third that of briquets. Moreover, there is much additional labor and inconvenience caused by handling and burning three times as many tons of lignite of large lumps in so greatly varying size.

The curves plotted in figure 5 show the characteristic rapid rise and fall of the ordinary lignite fire as contrasted with the gradual rise and prolonged continuation of the fire made of briquets.

COMPARATIVE BOILER TESTS OF BRIQUETS.

In order to prove the relative value of lignite briquets (semi-carbonized) for steaming and power purposes, the briquets have been used under numerous types of boilers with excellent satisfaction.

The table following gives the results of carefully conducted evaporative tests made with the same boiler, by the same fireman, and under as nearly as possible identical conditions, lignite semicarbonized briquets and Youghiogheny soft coal being used alternately. The boiler used was of the return tubular type, 16 feet long and 66 inches diameter, with 66 3½-inch tubes. The grates were stationary and of the herringbone type, with ½-inch openings and a grate surface 4½ by 5½ feet. The table follows:

Results of boiler tests of lignite briquets and soft coal.

Item.	Lign'te briquets.	Youghiogheny coal.
Heating surface of boiler .... square feet..	1,175	1,175
Grate area .... do....	24.75	24.75
Ratio of heating surface to grate area	48.1	48.1
Average steam pressure .... pounds..	114.2	115
Average temperature of feed water, ° F	65	65
Fuel used per hour .... pounds..	381.8	380.2
Fuel used per hour per square foot of grate area .... per cent..	15.4	15.35
Fuel used per horsepower-hour .... do....	3.76	3.88
Proportion of ash in fuel .... do....	10.76	8.84
Proportion of clinker .... do....	0.93	4.11
Proportion of combined ash and clinker .... do....	11.69	12.95
Actual quantity of water evaporated per hour .... pounds..	2,931.9	2,838
Actual quantity of water evaporated per square foot of heating surface per hour, pounds	2.49	2.41
Actual quantity of water evaporated per pound of coal .... pounds..	7.68	7.46
Quantity of water evaporated per hour, from and at 212° F .... do....	3,503.3	3,380
Quantity of water evaporated per square foot of heating surface per hour, from and at 212° F .... pounds..	2.98	2.89
Quantity of water evaporated per pound of coal, from and at 212° F .... do....	9.18	8.88
Average boiler horsepower developed	101.5	98

Lignite briquets gave good satisfaction in the various kinds of burning tests to which they were put. They burned with an even fire and with a gentle, smokeless flame, gradually burning from circumference to center. They showed no signs of disintegration during the burning. They stood poking and shaking satisfactorily. The unburned parts of the briquets remained hard and strong until entirely consumed. In several tests briquets were taken from the fire and while still red hot were immersed in cold water. The severe treatment produced no appreciable effect, as they remained hard and did not disintegrate or even crack.

They burned on the grate perfectly, leaving no unburned lumps such as are left in the burning of ordinary coal. The ash is fine and granular, readily sifts through the grates, and contains only a trace of unburned coal or carbon. In this respect the lignite briquets are remarkable, as shown by the analyses of the ash from anthracite coal and from lignite briquets. The anthracite ash contained 43.5 per cent unburned combustible matter, whereas the lignite ash contained only 3.6 per cent.

An analysis was made of the ash from each test to determine the proportion of combustible matter. The proportion in the anthracite coal ash will be seen to have been considerable, but there is almost no combustible matter left in the ash from the briquet. This is one reason why in the actual burning tests lignite briquets gave such high efficiency.

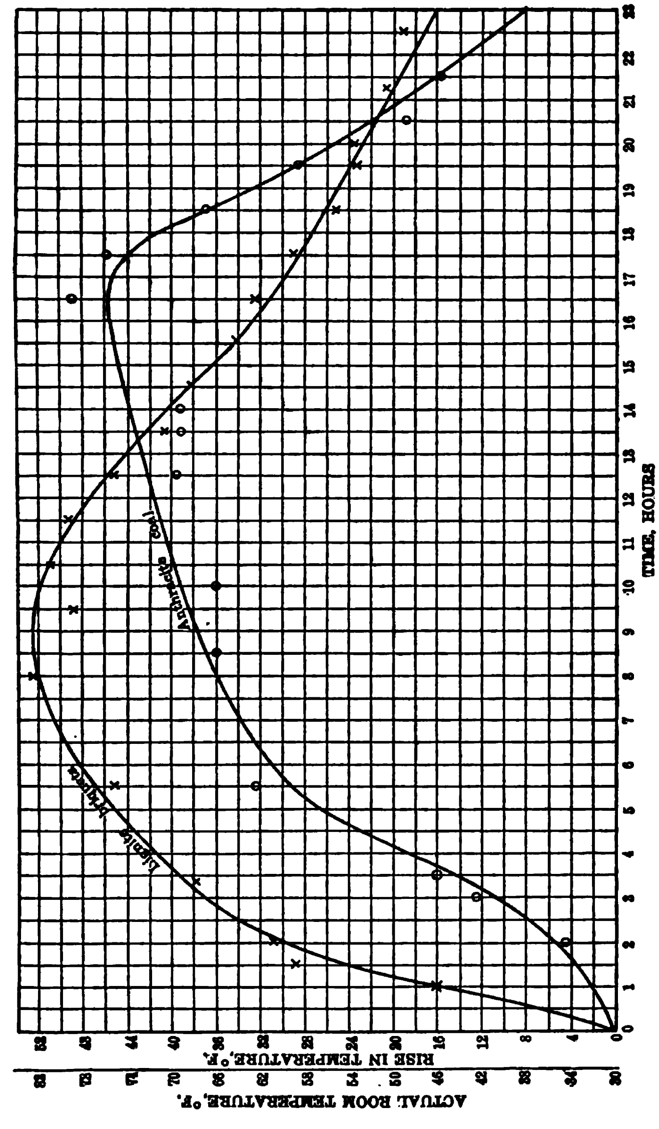


FIGURE 3.—Curves showing relative heat values obtained by burning lignite briquets and anthracite coal in self-feeding, base-burner, hard-coal stove.

SUMMARY.

To one thoroughly familiar with the great extent of the Western lignite deposits, their limited development, and the comparatively simple methods that have thus far been adopted in their utilization as fuel, any investigations looking to a possible and increased utilization of these vast deposits must at once be considered of great economic importance. There is no doubt but that much can be done toward improving the methods of burning now in use, and in providing means for using the coal in other forms, such as in a pulverized state, or in the manufacture of producer gas, or of by-product gas, or as residue briquets. Especial attention has been given by the writer to the study of utilizing the lignite in the form of residue briquets and in the manufacture of by-product gas, because in this

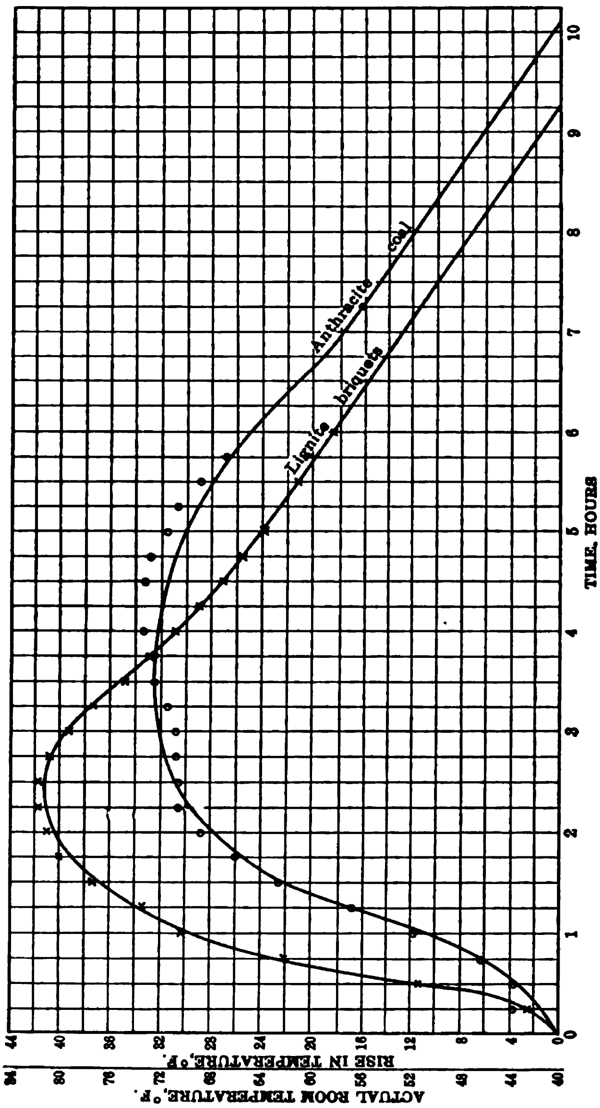


FIGURE 4.—Curves showing relative heat values obtained by burning lignite briquets and anthracite coal in a direct-draft stove.

method there appear excellent possibilities of providing a satisfactory and efficient fuel and of recovering numerous by-products.

From the results obtained by the methods being developed at the school of mines and the substation of the University of North Dakota there seems little doubt but that the briquetting and the production of gas from lignite can in the near future be put on a commercially satisfactory basis.

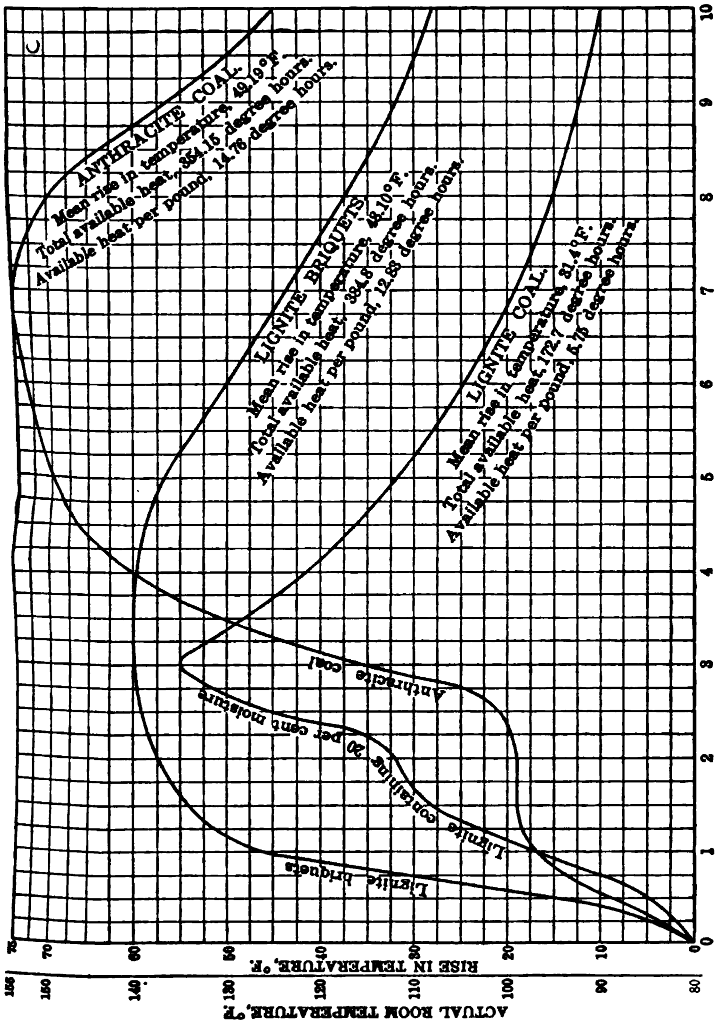


FIGURE 5.—Relative rise and fall of lignite, lignite-briquet, and anthracite fires.

Because of the ease with which the gas is produced, the low price of the original lignite, the value of the residue, and the low price for which it could be sold if manufactured in a plant used to produce briquets from the residue, the lignite gas should have a large commercial utilization for heating, lighting, and power purposes. It has been found that briquets made from this concentrated residue produce a most excellent fuel, for all practical purposes approaching the efficiency of anthracite. One ton of the air-dried lignite will produce from a half to two-thirds of a ton of briquets in addition to 8,000 or 10,000 cubic feet of gas. The briquets have about twelve-thirteenths the actual heating value of hard coal, and they can be shipped for considerable distances and still prove profitable. The briquets present many advantages, especially over the original lignite as usually placed on the market. The heating value is nearly doubled, the briquets do not disintegrate on standing or burning, they can be stored without being affected by atmospheric conditions, they are uniform in size and are convenient to handle.

No detailed statements of the cost of operating a large commercial plant are given in this report for the reason that the cost per ton of briquets and per 1,000 feet of gas and other by-products will depend upon a large number of factors, any one of which may materially affect the cost. For example, the cost of production is much less in a large plant than in a small one, and also less in a plant favorably situated—that is, near a mine, a city, and railway facilities. The use of mine slack, the percentage of moisture in a given lignite deposit, and the relative cheapness of mining and ease of delivery to the plant are all variable conditions and would have to be determined for each individual plant.

In addition the plant could be operated under many modifications of the general process that has been explained; for example, all or a part of the gas might be sold for heating or lighting purposes or converted into electricity. The extraction and production of gas might be carried further in one plant than in another, or the by-products, such as tar and ammonia, could be recovered and marketed, used in part, or entirely neglected. Differences in any of these conditions would materially modify the cost of production.

In general the larger the plant and the more complete the saving of by-products the smaller will be the cost of production. It is believed that in a carefully constructed and operated plant the saving and utilization of the various by-products will so reduce the cost of operation as to make the industry commercially practical and profitable.

All of the data obtained from the investigations and the operation of the experimental plant indicate that a plant of fair capacity, if so constructed as to economize in the original cost, as well as in the cost of operation, and if operated efficiently and under careful management, should turn out excellent commercial products at a cost that would admit of a fair profit.

In order to establish the industry successfully great care should be taken in planning and operating the plant, and the methods employed should follow very closely those that have proved satisfactory in the experimental work, the principles of which are outlined in this report.

Although the general principles involved in the process explained in this report are not complicated, the proper observance of the many details of operation is essential to success, and those managing and operating the plant should have had technical training and experience.

The development of methods for the utilization of low-grade coal will prove of much value to those communities nearest the great lignite deposits in the West. In some of these the lignite could be converted into electricity, which in turn could be sent to surrounding towns and villages, thus distributing power and light from numerous central power plants. Such an arrangement would not only be a great saving of our fuel resources but would also result in the establishment of many industries that can be developed by abundant and cheap electric power.

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Bulletin 90 Law Serial 3

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
JOSEPH A. HOLMES, DIRECTOR

ABSTRACTS OF CURRENT DECISIONS
ON
MINES AND MINING

DECEMBER, 1913, TO SEPTEMBER, 1914

BY

J. W. THOMPSON

WASHINGTON
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First edition. December, 1914.

PREFACE.

This bulletin is the third of its kind to be published by the Bureau of Mines, the two preceding being Bulletin 61 and Bulletin 79.

The wide demand for the information contained in these bulletins has led the bureau to decide to issue similar bulletins with sufficient frequency to keep reasonably current the records of decisions of Federal and State courts of last resort on questions relating to the mineral industry.

The bureau will gladly welcome and consider any suggestions looking to improvement in the matter contained in these bulletins or the manner in which it is presented. The purpose of the bulletins will continue to be to improve directly or indirectly mining conditions and to promote the health and safety of miners by the prompt publication of decisions, and to this end it is desired that the bulletins reach all persons who are interested.

J. A. HOLMES.

GENERAL SUBJECTS TREATED.

Minerals and mineral lands.
Mining terms.
Mining corporations.
Mining claims.
Statutes relating to mining operations.
Mines and mining operations.
Mining leases.
Mining properties.
Damages for injuries to miners.
Quarry operations.
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ABSTRACTS OF CURRENT DECISIONS ON MINES AND MINING, DECEMBER, 1913, TO SEPTEMBER, 1914.

By J. W. Thompson.

MINERALS AND MINERAL LANDS.

MINERALS.

ORES—PROCESS OF ORE CONCENTRATION—PATENTABILITY.

The patent issued to Sulman, Pickard, and Ballot, November 6, 1905, and assigned to Minerals Separation and Minerals Separation American Syndicate, for new and useful improvements in ore concentration, its object being to separate metalliferous matter from gangue by means of oils and fatty acids that have a preferential affinity for such metalliferous matter, the principal feature of which is "agitating the mixture to cause the oil-coated mineral to form a froth," was clearly anticipated by other patents, and each step in the process described in the Sulman, Pickard, and Ballot patent is fully described in more than one of the prior patents, with the single exception of the reduced quantity of oil used; but the discovery that the small fraction of oil is sufficient to produce flotation of the metalliferous matter can not be made by itself or in combination, the subject of a patent.

Hyde *v.* Minerals Separation, 214 Fed., 100, p. 109, May, 1914.

ACTION FOR CONVERSION OF MINERALS.

In an action by the grantor of a certain mine and mining property against his grantee to recover damages for the conversion of a quantity of ore that the grantor before the conveyance had mined and extracted from the mine and placed on the dump near the mine, the plaintiff is not entitled to recover where it appears that at the time the ore was placed on the dump the mine was owned and operated by a mining company and that at the time the ore was taken out of the mine the company had no intention of doing anything with it but simply deposited it on the dump as waste and to give an opportunity to develop the mine and get better ore to send to the smelter, and that

at the time the ore was placed on the dump it was considered to be of no value, as in such case the ore so deposited remained a part of the realty and passed with the deed.

Pittsmont *v.* Omega Copper Co. (Arizona), 141 Pacific, 847, p. 848, July, 1914.

SALE AND CONVEYANCE.

SALE OF TAILINGS—LIABILITY FOR CONVERSION.

A grantee under a contract to purchase an interest in mining property and by which he was given immediate possession of such mining property, with full power and license to prospect upon, work, develop, extract, and remove ore therefrom, and to continue the possession for 90 days, is liable, on failure to complete the purchase of the property, where after the expiration of the 90-day period he entered upon the mining property under a separate and subsequent contract and removed therefrom and appropriated to his own use a large amount of valuable ore in the form of tailings placed by him upon the dump pile during his possession under the former contract, as such tailings, on his failure to complete his contract of purchase continued to be the property of the grantor, and the subsequent contract authorized him to extract and remove ore from the mine only.

Savage *v.* Nixon, 209 Fed., 122, October, 1913.

CLASSIFICATION OF MINERAL LANDS FOR PARK PURPOSES.

The act of March 2, 1899 (30 Stat., 993), creating Mount Ranier National Park, limited the right of selection to nonmineral public lands so classified as nonmineral at the time of actual government survey, but a selection valued for certain like purposes may be made of lands not classified as nonmineral, as the right of selection extends to unsurveyed lands, which in the nature of things can not be so classified, and such a selection is not invalid by the fact that the mineral surveyor did not classify it as nonmineral, and under the practice prevailing in the Land Department the absence of a classification as mineral is equivalent to and is to be understood as a classification of nonmineral.

West *v.* Edward Rutledge Timber Co., 210 Fed., 189, p. 195, July, 1913.

CONTRACT OF PURCHASE—CONSIDERATION.

A contract for the purchase of certain mining property providing for the payment of $100,000, $10,000 to be paid upon the signing of the agreement and the remaining $90,000 to be paid upon the delivery of the deed, together with an agreement to pay the vendor amounts in the aggregate to the sum of $1,000,000, 25 per cent of the net profits resulting from the operation of the mining properties, is not an absolute agreement to pay $1,000,000 for the property, nor is that the estimated value of the property, but is an agreement for a share in the profits of mining operations, and the payments are wholly contingent upon the success of such operations and must be measured by the amount of profit, the payment of which depends on the success of the enterprise, but in no event to exceed the amount of the remaining $900,000.

Consolidated Arizona Smelting Co. *v.* Hinchman, 212 Fed., 813, p. 815. March, 1914.

COVENANTS NOT RUNNING WITH LAND.

An agreement reciting that in consideration of the execution and delivery of a deed to certain mining property and the sum of $1 the purchaser agreed to pay or cause to be paid to the original grantor of such property 25 per cent of the net proceeds resulting from the operation of the properties until there shall have been paid the aggregate sum of $1,000,000, the payments to be made quarterly or as soon thereafter as the net profits for the preceding quarter can be ascertained; and it was further agreed that the net profits should be the net proceeds from the operation of the mining properties after deducting the cost of mining, development work, transportation, treatment, and smelting, and all property charges incidental thereto, do not constitute a covenant that runs with the land, but is personal merely, and does not create an equitable charge on the property, and a purchaser with notice of the agreement is not bound to operate the properties and pay the vendor the stated percentage of the net profits.

Consolidated Arizona Smelting Co. *v.* Hinchman, 212 Fed., 813, p. 817, March, 1914.

MINERAL INTERESTS AS REALTY.

Mineral interests are a part of the realty and the estate in them is subject to the ordinary rules of law governing the title to real property.

Hoilman *v.* Johnson (North Carolina), 80 Southeastern, 249, p. 250, December, 1913.

PRESUMPTION AS TO OWNERSHIP.

The presumption that the person having possession of the surface has the possession of the subsoil containing the minerals does not exist when the surface mineral rights are severed.

Hoilman *v.* Johnson (North Carolina) 80 Southeastern, 249, p. 250, December, 1913.

MINERAL INTERESTS—NOTICE OF CLAIM.

Mineral interests in land means all the minerals beneath the surface; and when a person claiming the ownership of the minerals sinks a shaft or opens a mine or gives notice of his claim to all such interests included in his deed and not to one particular mineral only, he is not required to mine for every known mineral in order to give notice that he claims the entire mineral interests.

Hoilman *v.* Johnson (North Carolina), 80 Southeastern, 249, p. 251, December, 1913.

CONVEYANCE OF MINERALS AND GRANT OF MINING RIGHT—DISTINCTION.

There is a clear distinction between an absolute conveyance of minerals in place and the grant of a mining right to another upon certain described land to convert the mineral into personalty and dispose of it. In the former case there is a severance of the title to the realty; in the latter, there is not, although the mining right entitles the grantee to extract every particle of the mineral, but the grant is not of the mineral in place, but only of the mineral rights and privileges.

Chandler *v.* French (West Virginia), 81 Southeastern, 825, p. 827, May, 1914.

CONSPIRACY TO PURCHASE—PROOF OF FRAUD.

A sale of mineral land can not be invalidated and set aside on the ground of alleged fraud in making the purchase where the person to whom the conveyance was made was not in any way connected with and had nothing whatever to do with the alleged conspiracy and fraud practiced on the grantor.

Hurst *v.* Duff (Kentucky), 160 Southwestern, 953, December, 1913.

MINERALS—ORE AS REAL ESTATE.

Where in the operation of a mine ore taken from the mine was placed upon the surface of the ground adjacent to and in the workings in and upon the mine, a sale and conveyance of the mine and mining property passes title to the ore so placed upon the surface of the ground, and the mere mental reservation of such ores, in the absence of a reservation in the deed, would not be sufficient to defeat the conveyance of the ore.

Pittsmont *v.* Omega Copper Co. (Arizona), 141 Pacific, 847, p. 848, July, 1914.

SURFACE AND MINERALS—OWNERSHIP AND SEVERANCE.

RESERVATION OF MINERALS.

A deed conveying certain described land but excepting and reserving to the grantor all mineral upon or in such land, including coal and iron, and reserving the use of such surface ground as may be necessary for exploring and mining and carrying away the mineral, does not convey the entire estate to the land described, but carves out an interest which the grantor retains, and this constitutes an interest in real estate and is properly classified as property.

Northern Pac. R. Co. *v.* Mjelde (Montana), 137 Pacific, 386, p. 387, December, 1913.

SEPARATE OWNERSHIP AND ESTATES.

There may be several estates in the same land owned by different persons, one owning the surface, another the timber, and a third the minerals underground, each being a separate estate and each may be subject to taxation.

Northern Pac. R. Co. *v.* Mjelde (Montana), 137 Pacific, 386, p. 391, December, 1913.

SEVERANCE BY DEED.

The surface of the earth and the minerals under the surface may be severed by a deed or by reservations in a deed, and when so severed they constitute two distinct estates.

Hoilman *v.* Johnson (North Carolina), 80 Southeastern, 249, p. 250, December, 1913.

SEVERANCE—EFFECT OF ADVERSE POSSESSION.

The owner of the surface can acquire no title to minerals beneath the surface by exclusive and continuous possession of the surface alone, nor does the owner of the minerals lose his right or his possession by any length of nonuser, but he must be disseized to lose his right, and there can be no disseizin by any act which does not actually take the minerals out of his possession.

Hoilman *v.* Johnson (North Carolina), 80 Southeastern, 249, p. 250, December, 1913.

SALE OF MINERAL IN PLACE—RIGHT OF SUPPORT FOR SURFACE.

Where the estate in minerals in place is severed from the estate in the surface, the owner of the latter has the right to subjacent support for the surface; but the right to such support may be waived or conveyed by the owner of the surface to the owner of the minerals.

Walsh *v.* Kansas Fuel Co. (Kansas), 137 Pacific, 941, p. 942, January, 1914.

TAXATION OF MINERALS.

Mining rights and interests in minerals are the subject of horizontal severance from the surface and taxable as real estate.

Riggs *v.* Board of Commissioners, Sullivan County (Indiana), 103 Northeastern, 1075, p. 1077, January, 1914.

SEPARATION OF MINERAL AND SURFACE ESTATE.

The owner of land containing minerals may segregate the mineral estate from the rest of the land and convey either interest without the other; and a deed conveying a tract of land but reserving all ores, mines, minerals, mineral oils, and mineral paints, which may be in or upon the land, with the privilege of searching, boring, digging, and mining therefor and with the right to build and remove structures needed for mining operations, is a valid reservation and effectually severs the surface and mineral estates.

Washburn *v.* Gregory Co. (Minnesota), 147 Northwestern, 706, p. 707, May, 1914.

SEPARATION OF SURFACE AND MINERALS—QUIETING TITLE—POSSESSION.

The grantee of minerals in and under certain land may sue a subsequent grantee of the surface from the common grantor to quiet his title to the minerals without being in actual possession.

Kentenia Corporation *v.* Boreing Land & Min. Co. (Kentucky), 166 Southwestern 780, May, 1914.

COAL AND COAL LANDS.

ADVERSE POSSESSION INSUFFICIENT.

An adverse possession of coal land consisting in the use of a portion of the surface by depositing thereon culm and fine unmarketable coal, and by mining coal beneath the surface, does not constitute actual possession essential to the validity of an adverse possession that confers title, where the rightful owner had no actual knowledge that coal was being mined and there was nothing on the surface that indicated the actual mining of coal.

Stark *v.* Pennsylvania Coal Co. (Pennsylvania), 88 Atlantic, 770, p. 771, June, 1913.

CONVEYANCE OF COAL IN PLACE—RIGHTS AND DUTIES OF GRANTEE.

A lease by the owner of land by which he granted to the lessee the coal underlying the land described and granting the use of the surface for the working and management of the mine, the lease to continue until the coal was worked out unless forfeited by failure to comply with the conditions therein stated, and providing that the lessee was to work and mine the coal in a good, careful, and workmanlike manner and not leave any coal that could be mined with safety, the lessee agreeing to pay a royalty of 10 cents per ton except on coal necessarily used in operating the mine, does not waive the lessor's right to subjacent support of the surface, and the lessee is liable for damages to the surface caused by reason of his not leaving or furnishing subjacent support to the surface.

Walsh *v.* Kansas Fuel Co. (Kansas), 137 Pacific, 941, p. 942, January, 1914.

KNOWLEDGE OF USE—FAILURE OF TITLE—ABATEMENT OF PRICE.

Where the owner of coal land sold a part of the surface to a coal company operating on adjoining lands with the knowledge that it was the purpose of the coal company to enlarge its plant and extend its operations, the grantor may be compelled to make an abatement in the purchase price sufficient to purchase an outstanding lease or conveyance formerly made by him to another coal company and which was inconsistent with the use of the land intended by the latter grantee.

Marrowbone Coal & Coke Co. *v.* Coleman (Kentucky), 161 Southwestern, 238, December, 1913.

SALE OF COAL IN PLACE—RIGHT OF SURFACE SUPPORT.

Where the owner of land retains the surface estate and conveys the estate in minerals thereunder, he may convey or waive the right of subjacent support for the surface; but such conveyance or waiver should not be implied unless the language of the deed is appropriate therefor and clearly indicates such to be the intention of the parties to the conveyance.

Walsh *v.* Kansas Fuel Co. (Kansas), 137 Pacific, 941, p. 942, January, 1914.

SEVERANCE OF OWNERSHIP—RELATIVE RIGHTS OF OWNERS OF SURFACE AND OF MINERALS.

Where an easement for a right of way is granted to a railroad company across the lands of another, the owner of the fee remains the owner of all mineral in the land and may make all lawful use of the land so long as he does not interfere with the free use of the right of way; and the railroad company as the owner of the easement has the right to occupy the surface of the land, and the land owner has the right to mine for coal thereunder, and it is the duty of each to use his property so as not to unlawfully interfere with the other's rights, and if tunnels, air passages, and entries are constructed by the landowner beneath the right of way for the purpose of mining for coal, the railroad company is liable in damages for causing a destruction of such tunnel, air passage, or entry.

Cincinnati, etc., R. Co. *v.* Simpson (Indiana), 104 Northeastern, 301, p. 306, February, 1914.

MINING BY PERSON IN ADVERSE POSSESSION—LIABILITY.

A person in adverse possession of coal lands and mining coal therefrom is not liable in an action of trover for the conversion of the coal at the suit of a person claiming the legal title to the land; but the mere act of the person in possession in mining the coal does not give such an actual adverse possession as will defeat an action by the owner of the legal title claiming constructive possession by reason thereof.

Pearce *v.* Aldrich Min. Co. (Alabama), 64 Southern, 321, p. 323, February, 1914.

METHOD OF ACQUIRING TITLE.

Mineral lands including coal lands are not subject to acquisition under the homestead laws.

Diamond Coal Co. *v.* United States, 233 U. S., 236, p. 238, April, 1914.

SALE AND TITLE—PROOF OF PRICE—GOOD FAITH.

In an action of ejectment to recover all the coal and other minerals in and under a certain parcel of land, where the plaintiff claimed as a purchaser for a valuable consideration without notice of a prior conveyance, it is proper for the defendant to prove that the plaintiff knew that as a rule titles were defective in the particular locality, and it is proper to show that he paid the sum of $125 for 1,000 acres of land admittedly worth more than $2,000, as such evidence tends strongly to show that the plaintiff realized at the time he made the purchase that he was taking a speculative risk as to the validity of the title, and for the plaintiff to prevail as a purchaser for value without notice it was incumbent upon him to show that he paid a fair value for the property and purchased it without notice.

Clinchfield Coal Corporation *v.* Steinman, 213 Fed., 557, p. 561, March, 1914.

CONTRACT FOR SALE OF COAL.

A conveyance and lease by which the grantor demises and leases unto the grantee "all coal and mineral rights and privileges whatsoever, contained on, in, and beneath the surface" of certain described land, the grantee to have and hold the same for the term and period, of 99 years, the said grantee to pay or cause to be paid during the said term, for and in consideration of the demise and lease, "a rent of 3 cents per ton of 2,240 pounds for each and every ton of coal and other minerals mined and shipped therefrom" does not vest in the grantee an estate in the coal and other minerals in place, nor does it in terms purport to convey title to the mineral, where the grantee is not required to commence mining at any certain time, and where he never did in fact begin mining operations; but the title to the minerals remained in the lessor subject to the right of the lessee or grantee to sever it from the other part of the realty, but the grantee was vested with no present title to the coal in place.

Chandler *v.* French (West Virginia), 81 Southeastern, 825, p. 826, May, 1914.

AUTHORITY TO MINE NEAR DIVISION LINE.

A deed granting all the coal in and under the land described, and providing that "with the coal hereby conveyed there is also granted and conveyed unto the said party of the second part all the usual mining privileges for the removal of the same and every part thereof from, under, and in said parcel of land, such as are vested in the said parties of the first part," does not authorize the grantee to mine the coal within 5 feet of the dividing line between the grantor and grantee as against the statute of West Virginia (sec. 3920, Code 1913), which prohibits the owner or tenant of any land containing coal from removing the coal within 5 feet of the division line under penalty.

Darby *v.* Davis Coal & Coke Co. (West Virginia), 81 Southeastern, 1124, May, 1914.

RESERVATION—ABATEMENT OF PURCHASE PRICE.

Where a conveyance with warranty of certain coal lands reserved all the coal except what was reserved in a prior deed conveying the coal, and where it appeared that in the conveyance referred to there was in fact no reservation of coal, the grantee can not demand an abatement of the purchase price on the ground of a breach of the covenant of warranty, as in such case it can not be known from the deed what area, estate, or right as to coal was warranted, and the right to abatement for loss by defect of title must be governed by the deed as it is, not by what it ought to have been.

Cummings *v.* Hamrick (West Virginia), 82 Southeastern, 44, p. 45, May, 1914.

CONTRACT FOR SALE OF COAL—PRICE.

A contract for the sale of coal and the output of the mine provided among other things that prices named in the contract are based on the present Michigan mining rates of $1.01 per ton, and shall be increased or reduced on all sizes of coal as the mining rate may advance or decline during the life of the contract, and this is an established basis for establishing the price of the coal sold or delivered under the contract, and where the rate of mining was subsequently increased by an agreement between the operators and the miners' union and was fixed at $1.06 per ton this likewise furnished a definite basis for establishing the price of the coal delivered under the contract and was not affected by other items connected with the cost of mining.

Caledonia Coal Co. *v.* Consolidated Coal Co. (Michigan), 148 Northwestern, 187, July, 1914.

RESERVATION OF COAL—CONSTRUCTION.

A bond for a deed for certain described land for a specific consideration binding the obligor to execute a warranty deed to the surface of such land, reserving the minerals and mineral rights of every sort and nature and the right of ingress and egress and a way to work and exploit the land at all future times, which right shall cease at the death of the obligor, is merged into a deed subsequently executed by the obligor and the intention of the parties is to be ascertained from the construction of the deed and not from the title bond, and specific performance of the title bond can not be awarded after the execution of the deed; and the right that ceased at the death of the grantor was the right to keep the surface for the purpose of mining or operating the coal at the stated damages per acre, but as the reservation of the mineral as expressed in the deed was for all future time the actual title of the mineral was reserved.

Creekmore *v.* Bryant (Kentucky), 164 Southwestern, 337, p. 338, March, 1914.

OIL AND OIL LANDS—SALE AND CONVEYANCE.

DEED IN ESCROW.

An agreement whereby the owner of certain oil lands delivered a deed to such land to a bank, and an oil company delivered its deed to certain lands to the same bank on condition that if a certain judgment was affirmed within 30 days the vendor in the first deed was to pay to the bank on the oil company's account a stated sum and the bank would thereupon deliver, respectively, the deeds mentioned, but on the failure of the first vendor to pay the amount stipulated all the deeds were to be delivered to the oil company, constitutes a delivery to the bank in escrow.

Doran *v.* Bunker Hill Oil Min. Co. (California), 139 Pacific, 93, p. 94, January, 1914.

DEEDS IN ESCROW—UNAUTHORIZED DELIVERY—TRUST.

In an action against an oil company to have a trust declared in real estate a complaint is sufficient for that purpose which alleges that the plaintiff and the defendant oil company each deposited deeds in a certain bank under an agreement by which the plaintiff was to pay to the bank on the oil company's account a certain stated sum within thirty days after written notice of affirmance of a certain judgment in a pending suit, and averring that the oil company upon false representations obtained the deeds from the depositary before the expiration of the stipulated time and took possession of the real estate described in the deed.

Doran *v.* Bunker Hill Oil Min. Co., 139 Pacific, 93, p. 95, January, 1914.

SPECIFIC PERFORMANCE OF CONTRACT.

The specific performance of a contract to sell and convey oil lands will not be denied the vendor merely because the evidence shows that the land can be sold on the market for the contract price.

Waratah Oil Co. *v.* Reward Oil Co. (California), 139 Pacific, 91, p. 92, March, 1914.

SPECIFIC PERFORMANCE OF CONTRACT—VALUE OF LAND.

In an action for the specific performance of a contract to sell and convey oil lands the market value of the land is the proper test where the value of the land contracted tō be sold becomes important.

Waratah Oil Co. *v.* Reward Oil Co. (California), 139 Pacific, 91, p. 92, March, 1914.*

CONTRACT OF SALE BY CORPORATION—INVALIDITY AND RATIFICATION.

A contract for the sale and conveyance of oil lands owned by a corporation, executed by the president and secretary, may be invalid for the reason that the corporation has no power to delegate to such officers the exercise of fundamental and basic principles outside of the ordinary course of business of the corporation, yet such a contract is ratified by the corporation acting under the contract as though its validity was unquestioned, and especially so where the board of directors of the corporation passed a resolution expressly ratifying the sale and caused a tender of a deed of the property to be made to the purchaser.

Waratah Oil Co. *v.* Reward Oil Co. (California), 139 Pacific, 91, p. 93, March, 1914.

CONTRACT FOR SALE OF OIL AND GAS—VALIDITY AND EFFECT.

A contract by which the purchaser bound himself to pay to the seller the sum of $10,000 for all of the oil, gas, coal, sulphur, and other minerals in and under a certain described tract of land that may be found by drilling and mining operations conducted on such land, with the right of ingress and egress at all times for the purpose of drilling, mining, and operating for such minerals, is a valid and binding contract for all the minerals in or under the land described and sufficiently identifies and describes the minerals, and the purchaser is liable for the full contract price and is bound to pay the stipulated price according to the terms of the contract whether he drills or mines for the minerals or not.

Whited *v.* Johnson (Texas Civil Appeals), 167 Southwestern, 812, p. 813, June, 1914.

MINING TERMS.

HITCHES.

Hitches are places cut in the coal or sides of a mine in which to rest the ends of timbers used in propping the roof.

Bracken *v.* Lam Coal Co. (Kentucky), 165 Southwestern, 686, April, 1914.

ROOM NECK.

A room neck is a term applied to a short passageway from the entry in the mine to the room which would afterward be opened beyond the room neck and in which the miner would work.

Gambino *v.* Manufacturers' Coal & Coke Co. (Missouri Appeal), 164 Southwestern, 264, p. 265, February, 1914.

BRUSHING.

Brushing denotes the digging out of the bottom or the mining off of the top of an entry or room for the purpose of admitting cars where the seam of coal mined out is too narrow or shallow for the admission of cars.

Williams *v.* Craig Dawson Coal Co. (Iowa), 146 Northwestern, 735, p. 736, April, 1914.

OUTCROP.

The word "outcrop" signifies the edges of strata which appear at the surface of the ground, or as a portion of a vein or strata emerging at the surface or appearing immediately under the soil and surface debris; and the word has been used in connection with a vein and in general comprehends the particular place and character of manifestation of mineral strata or vein, but does not necessarily imply the presentation of the mineral to the naked eye on the surface of the earth but it means that it comes so near to the surface of the earth that it is found easily by digging, or is the point at which the vein is nearest to the surface of the earth.

Sloss-Sheffield Steel & Iron Co. *v.* Payne (Alabama), 64 Southern, 617, February, 1914.

BAD PLACE.

A "bad place" within the meaning of a contract between the United Mine Workers and an Employers' Association is a place in the roof which can not be made reasonably safe by the ordinary propping usually done by the miner himself.

Duncan Coal Co. *v.* Thompson (Kentucky), 162 Southwestern, 1139, p. 1140, February, 1914.

MINING CORPORATIONS.

BANKRUPTCY—CLAIMS PROVABLE—BONDS PAYABLE OUT OF SURPLUS.

Bonds issued by a mining corporation containing a stipulation to the effect that the face value with interest is payable out of certain named funds to be created out of the surplus earnings of the company, and stipulating further to the effect that the lien provided for to secure the bonds was limited to such surplus earnings, do not create a debt provable in bankruptcy where it appears there never were any surplus earnings of the company and the funds out of which such bonds were payable were never in fact created or existed.

Synott *v.* Tombstone Consol. Mines Co., 208 Fed., 251, p. 254, October, 1913.

FEDERAL JURISDICTION—RESIDENCE OF PLAINTIFF.

A miner, a resident of the eastern district of Tennessee, may sue a nonresident corporation in the district of his residence for an injury sustained by him in the defendant's mine, where the amount in controversy brings the case within the jurisdiction of the Federal court.

Reich *v.* Tennessee Copper Co., 209 Fed., 880, p. 881, October, 1913.

BANKRUPTCY—PRIORITY OF CLAIMS.

Collaterals in good faith pledged by a coal company to a bank to secure a loan with which to liquidate the coal company's pay roll are valid in the hands of such bank after bankruptcy proceedings on the part of the coal company, as against the lien of an attachment levied after the assignment or bankruptcy.

Alabama Coal & Coke Co., In re, 210 Fed., 940, p. 945, December, 1913.

FRAUD OF OFFICERS—SETTING ASIDE CONVEYANCES.

A charge of fraud and mismanagement on the part of the officers of a mining corporation in an action by its stockholders to recover corporate property is sufficiently sustained by evidence showing that the corporation was possessed of property of the aggregate value of $2,000,000 and owed but a trifling amount of indebtedness aside from certain bonds; that the officers in control permitted one judgment of $14,000 and another of more than $1,000 to be recovered against the corporation when it had cash in hand, $20,000 and valuable salable personal property readily convertible into cash; that at a time when 12,000 shares of the capital stock were in the treasury worth on the market and salable for at least $60,000, the managing directors procured the issuance of executions on the two judgments, and a levy and sale to be made of property of the corporation worth at least $1,000,000 for the nominal sum of $1,200 and other property worth practically $1,000,000 to be sold for less than $5,000, all of which was purchased by a member of a reorganization committee, who subsequently received a deed from the sheriff as trustee for such committee, and where after the sales on execution had been made and the corporation divested of all its property the managing directors brought a suit for dissolution and obtained a decree on the ground that the corporation had disposed of all its corporate property; and where pursuant to the alleged scheme and conspiracy to obtain the property, the suing stockholder had been ousted from the office of director and president of the corporation.

Fleming *v.* Black Warrior Copper Co., Amalgamated (Arizona), 136 Pacific, 273, p. 274, November, 1913.

CONTRACTS WITH PROMOTERS—VALIDITY AND ENFORCEMENT.

A corporation formed by four persons as promoters, who became the sole stockholders and its officers and directors after incorporation, may ratify or adopt contracts made by such promoters prior to the incorporation and by such ratification will become liable thereon; and it may by such ratification or adoption make such contracts its own and use thereon its own name and may complete the specific performance of the contract made by such promoters with a third person by which the latter agrees to sell and convey certain described land to the corporation when organized.

Henry Gold Min. Co. *v.* Henry (Idaho), 137 Pacific, 523, p. 526, December, 1913.

FRAUDULENT SALE OF STOCK—RIGHT OF PURCHASER TO RELY ON REPRESENTATIONS.

The owner of all the stock of a mining corporation is liable for false and fraudulent representations in the sale of such stock where he represented to the purchaser that the stock was treasury stock and that the proposed sale was for the purpose of obtaining money for patenting the mining claims, that the company had contracted for building a smelter and it would have a valuable power site and had already entered into a contract with a smelting company for smelting its ores, and that it had in fact been offered $200,000 for the mining property, where the mining corporation had no treasury stock and had not in fact any legal stock whatever for the reason there had been no subscription to its capital stock and no conveyance to it of any mining property in lieu of stock subscriptions, and that it was not in fact possessed of any valuable property, and where it appeared that the money received from the purchaser was not applied in securing patents or otherwise improving the mining claim but was applied in the payment of former debts of the corporation; and the purchaser was not bound to make an independent investigation where the subject matter of the contract was not at hand and where the facts were within knowledge of the seller and could not be ascertained by the purchaser without trouble and expense, and the purchaser had the right under the circumstances to rely upon the representations made by the seller.

Borde *v.* Kingsley (Washington), 136 Pacific, 1172, p. 1173, December, 1913.

OFFICERS NOT PERSONALLY LIABLE.

The president of a mining corporation who employed a competent electrician to take charge of the construction work and install an electrical plant in connection with the operation of the mining company's business is not personally liable for the death of an employee of the company caused by an electrical shock.

Hill *v.* Pacific Gas & Electric Co. (California), 136 Pacific, 492, p. 496, November, 1913.

STOCK SUBSCRIPTIONS—CONDITIONS TO DOING BUSINESS.

The general statute of Washington relating to the organization of corporations provides that corporations for manufacturing, mining, and other purposes shall not commence business until the entire capital stock has been subscribed; but the statute relating to mining corporations provides that where the amount of the capital stock of the corporation consists of the aggregate valuation of the whole number of feet, shares, or interests in a mining claim, no actual subscriptions to the capital stock are necessary, and the transfer of the title to a mining claim is made a legal equivalent for the stock subscriptions, and to make the organization of a mining corporation legal the stock must be subscribed, or the mining company must be possessed in its own right of a mining claim for the working and development of which the corporation was organized, and in the absence of either of these requirements there can be no valid incorporation and no stock legally issued.

Borde *v.* Kingsley (Washington), 136 Pacific, 1172, p. 1173, December, 1913.

VALIDITY OF ORGANIZATION—COLLATERAL ATTACK.

A stockholder and a member of the board of directors of a mining corporation who has contracted with the corporation, purchased stock from and executed deeds to it, can not in a collateral suit avail himself of any defects in the organization, as this can be done only by the power creating the corporation in a direct proceeding constituted for that purpose.

Henry Gold Min. Co. *v.* Henry (Idaho), 137 Pacific, 523, p. 525, December, 1913.

CONTRACT WITH PROMOTERS—SALE OF STOCK—CONSIDERATION.

The holders of a bond upon a group of mining claims organized a corporation and became its managing officers, and during such time made a written proposition to the corporation to assign the bond in consideration of the issue of its capital stock, the corporation to assume and carry out all the terms of the bond and the bond to be taken in full payment of the subscription price of the stock; the corporation by an entry duly made in its record accepted the proposal and directed the issue of the stock upon an assignment of the bond, and the transaction was subsequently completed by the assignment of the bond and the issue of the stock, and the transaction, in the absence of the rights of creditors, was legal and binding on the parties and the consideration for the stock was legal and binding upon the corporation.

Gold Ridge Min. & Dev. Co. *v.* Rice (Washington), 137 Pacific, 1001, p. 1002, January, 1914.

PURCHASE OF MINING PROPERTY—EXTENT OF LIABILITY.

A mining corporation organized for the purpose of purchasing the property of an existing mining corporation, and which did in fact take over all the property of the existing corporation and exchange its stock for the stock held by stockholders in the old company, is liable for the existing debts of the old company; but it is not liable to the holder of a note executed by such old company that was in fact the personal obligation of the president of the old company and had by a fraudulent scheme of the president and the other managing officers of the old corporation become apparently a debt of such old corporation.

Otis *v.* Ohio Mines Co. (Arizona), 138 Pacific, 777, p. 778, February 1914.

CONVERSION OF STOCK—LIABILITY.

A mining corporation that refuses to register and transfer on its books a bona fide sale and transfer of its stock from a stockholder to a purchaser is liable in an action for conversion, and in an action for such conversion it is not necessary that the proof should be in strict conformity with the averment as to the date of the alleged conversion, and an allegation as to the time of conversion in such case is immaterial.

Robinson Min. Co. *v.* Riepe (Nevada), 138 Pacific, 910, p. 911, February, 1914.

LIABILITY FOR CONVERSION—MEASURE OF DAMAGES.

In an action by a stockholder against a mining corporation for conversion of stock in refusing to register a transfer of stock on its books the damages necessarily flowing from the wrongful act of conversion are the value of the property at the time of the alleged conversion with legal interest from that date to judgment.

Robinson Min. Co. *v.* Riepe (Nevada), 138 Pacific, 910, p. 912, February, 1914.

REFUSAL TO TRANSFER STOCK—DEMAND BEFORE SUIT UNNECESSARY.

In an action by a stockholder against a mining corporation for a conversion of stock in refusing to transfer the stock on its books, no demand is necessary before bringing suit, for the reason that the wrongful taking and conversion is an assertion of ownership, and the conversion takes place when the refusal is made to transfer the stock, and this of itself constitutes an assertion of ownership on the part of the corporation.

Robinson Min. Co. *v.* Riepe (Nevada), 138 Pacific, 910, p. 912, February, 1914.

FRAUD OF OFFICERS—NO DEMAND FOR SUIT.

Where officers of a mining corporation have had complete control of its affairs and have squandered its property and occupy hostile relations to the other stockholders and have in the management of the corporation entered upon a preconcerted plan to obtain for themselves the corporate property, and pursuant to such preconcerted action have obtained title to the property, the remaining stockholders are not required, before bringing suit, to demand that such officers bring suit in the name of the corporation to recover the property so squandered.

Fleming *v.* Black Warrior Copper Co., Amalgamated (Arizona), 136 Pacific, 273, p. 274, November, 1913.
Kleinschmidt *v.* American Mining Co. (Montana), 139 Pacific, 785, p. 788, March, 1914.

SPECIAL MEETINGS—NOTICE OF OBJECT.

The notice of a special meeting of the board of directors of a mining corporation need not specify the object of the meeting.

Waratah Oil Co. *v.* Reward Oil Co. (California), 139 Pacific, 91, p. 92, March, 1914.

POWER OF DIRECTORS—PAYMENT OF SALARIES.

The board of directors of a mining corporation has no inherent power to vote a salary to any director, as this power must emanate from the stockholders or from a by-law legally enacted or be authorized by statute, and in no event can the directors legally vote themselves compensation for past services; and when a director voluntarily or by the direction of the board assumes to perform the duties of secretary or treasurer without prearrangement by resolution or by-law or by contract, he is not entitled to recover for the value of his past services, and an appropriation and payment made by the board of directors for such services are equivalent to giving away the assets of the corporation.

Kleinschmidt *v.* American Min. Co. (Montana), 139 Pacific, 785, p. 789, March, 1914.

MISAPPROPRIATION OF FUNDS—RIGHT OF STOCKHOLDERS TO SUE—PARTIES.

Where the board of directors of a mining corporation refuses upon request to bring an action to recover money misappropriated by one of the officers, the stockholders themselves may sue on behalf of the corporation, and the right to sue does not depend upon whether the corporation was insolvent, but in such case the corporation itself is a necessary part, the action being for its benefit.

Kleinschmidt *v.* American Min. Co. (Montana), 139 Pacific, 785, pp. 788, 789, March, 1914.

AUTHORITY OF PRESIDENT TO EXECUTE NOTE.

The president of a mining corporation may be clothed with authority to execute a promissory note binding on the corporation.

Darrough *v.* Nevada Milling & Ore Purchasing Co. (Nevada), 140 Pacific, 724, p. 725, May, 1914.

DIVIDENDS—NOT PAYABLE OUT OF CAPITAL STOCK.

The rule that dividends can not be paid out of capital stock does not apply to a case where a corporation recovered a decree for large sums against a former officer for depreciating the capital stock, and the dividend proposed was to be paid out of the amount received on such decree, where in the meantime funds had been applied from the current net profits to the replacement of the impaired capital and the corporation has sufficient assets over all its liability to make good its capital and the money collected on such decree was not needed for the purpose of meeting any impairment of the money capital.

Hyams *v.* Old Dominion Copper Min. & Smelting Co. (New Jersey), 89 Atlantic, 37, p. 39, November, 1913.

DIVIDENDS—DISCRETION OF DIRECTORS.

The directors of a mining corporation acting upon their discretion in the declaration of a dividend are not to be controlled in such discretion at the suit of a stockholder on the ground that the directors were dominated by another corporation owning a majority of the stock and that the dividend was made pursuant to an agreement between the stockholders of the corporation in question and the stockholders of such dominating corporation, but to which agreement neither the directors themselves nor the corporation was a party.

Hyams *v.* Old Dominion Copper Min. & Smelting Co. (New Jersey), 89 Atlantic, 37, p. 40, November, 1913.

FRAUD OF DIRECTORS—RESCISSION OF CONTRACT.

In an action by a corporation against its directors and others for fraud in selling to the corporation in exchange for stock certain mining property, the fact that the land had been mined by the corporation and its value correspondingly diminished would not prevent the company from maintaining a bill for leave to rescind in so far as possible, and the court, if relief was granted, could impose such equitable conditions as would amply protect the rights of the defendants.

United Zinc Cos. *v.* Harwood (Massachusetts), 103 Northeastern, 1037, p. 1039, January, 1914.

FRAUDULENT ACT OF DIRECTORS—STOCKHOLDER'S RELIEF.

A court of chancery may relieve against the operation of a fraudulent action of a board of directors of a mining corporation at the instances of a single stockholder and in the absence of intervening rights of third persons; and stockholders of such a corporation who possess the major portion of its stock can not by force of their vote appropriate the property of the corporation to their own use in disregard of the rights of the minority stockholders.

Merriman *v.* National Zinc Corporation (New Jersey), 89 Atlantic, 764, p. 765, February, 1914.

DUTY AND LIABILITY OF DIRECTORS.

The directors of a mining corporation, while not responsible for errors in judgment in the administration of its business affairs, are fiduciaries charged with the duty of caring for the property of the corporation and of managing its affairs honestly and in good faith, and if this duty is violated, resulting in impairment of assets or injury to its property or unlawful profits to themselves, they may be compelled in equity to make full restitution; and if strangers combine and confederate with them they all may be sued jointly, and each is accountable for the funds or property unlawfully diverted.

United Zinc Cos. *v.* Harwood (Massachusetts), 103 Northeastern, 1037, p. 1038, January, 1914.

POWER OF BOARD OF DIRECTORS—RIGHT OF STOCKHOLDER TO INTERFERE.

A stockholder of a mining corporation can not maintain an action on behalf of the corporation for cancellation of a contract and lease entered into by the board of directors on the ground of personal interest and bad faith, by which the board had leased to a third person the exclusive right for mining for minerals for a period of 50 years in consideration of a payment of a certain per cent of the gross receipts from sales of ore where it appeared that at the time of the execution of the contract and lease the mining corporation was embarrassed and some of the members of the board of directors were under indictment and the corporation had been forbidden the use of the mails, and where under the conditions the mining company itself was unable to carry on mining operations, as the court will not interfere in the matter of the business management of a corporation within the powers of its board of directors, where the judgment of the board is honestly exercised; and the fact that private interests of members of such board, wholly unconnected with the contract authorized by the board, may be enhanced by the action taken, is not sufficient to justify an interference on the part of a court.

Merriman *v.* National Zinc Corporation (New Jersey), 89 Atlantic, 764, p. 765, February, 1914.

POWER OF COURTS TO CONTROL DIRECTORS—RIGHT OF STOCKHOLDERS.

The individual stockholders of a mining corporation can not question, in judicial proceedings, the corporate acts of the board of directors, where such acts are within the powers of the corporation and are in furtherance of its purpose, and are not unlawful or against good morals and are done in good faith and in the exercise of an honest judgment; but such matters must be left solely to the honest decision of the directors, and courts can not substitute their judgment and discretion in the place of the judgment of the directors.

Merriman *v.* National Zinc Corporation (New Jersey), 89 Atlantic, 764, p. 766, February, 1914.

STOCK CONTRACT WITH CREDITORS—ATTEMPTED RECISSION.

The judgment creditors of a mining corporation whose property had been sold on foreclosure entered into a contract with certain third persons that in consideration that such third persons should organize another mining corporation and would issue a certain stated amount of its stock to such judgment creditors of the old corporation the judgment creditors would not redeem the mining property from such foreclosure sale, as contemplated by them in order to protect their interests, and such contract after completion and after the parties have acted thereon can not be rescinded by one of such third persons by mere notice that such third persons will not proceed further under such contract, and the new corporation organized by such third persons may, on failure to issue the stock pursuant to such agreement, be compelled to do so or be liable in damages as for a conversion of stock.

Clapp *v.* Gilt Edge Consol. Mines Co. (South Dakota), 144 Northwestern, 721, p. 722, December, 1913.

INTERESTED STOCKHOLDERS—RIGHT TO VOTE.

There is no such recognized trust relation between stockholders of a mining corporation as will impose upon one who may be interested in the transaction, the authorization of which is being acted upon at a stockholders' meeting, the burden of establishing his good faith in the vote which he casts, as the stockholders do not hold fiduciary relations to each other in the sense that one is prevented from voting at a stockholders' meeting on a question in which he has an individual interest.

Merriman *v.* National Zinc Corporation (New Jersey), 89 Atlantic, 764, p. 767, February, 1914.

SUBSCRIPTION TO CAPITAL STOCK—DELIVERY TO PROMOTOR.

A promotor of a proposed corporation who solicits and procures stock subscriptions to a mining corporation to be organized is the agent of the body of the subscribers to hold the subscriptions until the corporation is formed and then turn them over to it without any further act of delivery on the part of the subscribers; and in such case a delivery of a subscription to such promoter is a complete delivery and binding on the subscriber.

Clapp *v.* Gilt Edge Consol. Mines Co. (South Dakota), 144 Northwestern, 721, p. 724, December, 1913.

LIABILITY FOR STATUTORY PENALTY—MINING NEAR DIVISION LINE.

A corporation operating a coal mine may be liable for the statutory penalty for the act of its servants in mining within 5 feet of a division line in violation of a statute, and it is sufficient in such an action to render a mining corporation liable, for the plaintiff to prove that such mining was done by its servants, as a failure on the part of the corporation to see that its servants obey the statute is its own nonobservance of the statute; nor is it a defense for the corporation to say that it notified its mine manager to observe the property line, and the act of the manager and servants at the mine in such a particular is the act of the corporation itself.

Gawthrop *v.* Fairmount Coal Co. (West Virginia), 81 Southeastern, 560, p. 561, April, 1914.
Darby *v.* Davis Coal & Coke Co. (West Virginia), 81 Southeastern, 1124, p. 1125, May, 1914.

LIABILITY AS PUBLIC-SERVICE CORPORATIONS.

A mining corporation whose charter authorizes only the mining and sale of coal and the exercise of incidental rights to such business may be liable and subject to all regulations of a public-service corporation where it engages in the work of supplying, from an electrical plant installed and maintained formerly for the operation of its mining property, electricity for the lighting of its stores, offices, and tenement houses, and also furnishes practically all other persons resident in the immediate vicinity of its stores and offices with electricity at uniform rates of compensation, the corporation by its servants and agents wiring the buildings and furnishing such persons fixtures for using the electricity, as it thus becomes a public-service corporation within the meaning of the public-service corporation act of West Virginia.

Wingrove *v.* Public Service Commission (West Virginia), 81 Southeastern, 734, p. 735, April, 1914.

EXERCISE OF EMINENT DOMAIN—REMEDY.

The owner of mineral land, a right of way over which has been appropriated by a public-service corporation, must obtain redress in condemnation proceedings and the statutory remedy in such cases is exclusive, and the landowner can not sue in ejectment nor is he entitled to an injunction which will have the effect of dispossessing the public-service corporation from a right of way occupied by it; and the rule applies though the public-service corporation may have secured such right of way in an illegal manner.

Tennessee Coal, Iron & R. Co. *v.* Paint Rock Flume, etc., Co. (Tennessee), 160 Southwestern, 522, p. 523, November, 1913.

PROPERTY SUBJECT TO EMINENT DOMAIN—DAMAGES.

A corporation organized to mine, coke, and sell coal has authority to own and hold such real estate as is reasonably necessary or incidental to the exercise of the powers for which it was incorporated, and the exercise of such powers requires that it have authority to secure coal to mine, coke, and sell, and this may require the purchase of the surface of the land in order to secure the coal beneath, and having purchased land for such purpose and during the ownership thereof it may use the surface for agricultural or other purposes, and as such owner of the surface the coal corporation may be entitled to damages for any permanent injury to the surface in the exercise of the right of eminent domain by any other corporation or person.

La Salle County Carbon Coal Co. *v.* Sanitary District (Illinois), 103 Northeastern, 175, p. 176, December, 1913.

KNOWLEDGE OF OFFICER NOT NOTICE TO CORPORATION.

A mining corporation organized for operating coal mines under a lease given to three partners providing for the payment of a stipulated royalty is not bound by an independent agreement made by such partners with the lessor to the effect that in case the mine was operated by third persons or by a corporation organized for that purpose an increased royalty should be paid, from the fact that one of such partners was elected president of the corporation, as in such case the partner, though president of the corporation, was acting for and on behalf of himself and partners and not for the corporation.

Rockport Coal Co. *v.* Carter (Kentucky), 163 Southwestern, 734, p. 735 (February, 1914.

PERSONAL LIABILITY OF OFFICERS.

The managing officer of a corporation who knowingly permits the tailings of the mining corporation to be thrown upon the lands of another, and who had been warned by the landowner and notified not to permit the accumulations of tailing on his land, is a joint tort feasor with the corporation and personally liable in an action for damages.

Robinson *v.* Moark Nemo Consol. Min. Co. (Missouri Appeals), 163 Southwestern, 855, p. 888, February, 1914.

LIABILITY OF DIRECTORS FOR DEBT OF CORPORATION—IMPLIED ASSENT.

The directors of a mining corporation that was insolvent and had no credit are personally liable to a bank for a loan made, where it was stated by the officer of the bank that the bank would let the corporation have the money if the directors would be personally responsible, and where the directors said nothing but permitted the money to be loaned which they knew could not be borrowed on the credit of the company, and which was in fact applied to the payment of the debts of the mining company.

Uvalde National Bank *v.* Brooks (Texas Civil Appeals), 162 Southwestern, 957, p. 958, January, 1914.

POWER OF OFFICER.

The president, secretary, or general manager of a mining corporation has no power, by reason of his office alone, to sell or lease the property of the corporation.

Franklin *v.* Havalena Min. Co. (Arizona), 141 Pacific, 727, p. 730, June, 1914.

FAILURE TO COMPLY WITH LOCAL LAWS—TITLE TO REAL ESTATE.

The statute of Idaho requires a foreign corporation to file in the office of the clerk of the district court of the proper county its designation of an agent, and expressly provides that no foreign corporation can take or hold title to real estate prior to making such filing, and the statute in this respect is mandatory, and a conveyance made to a foreign mining corporation that has failed to comply with this requirement is null and void.

Dickens-West Min. Co. *v.* Crescent Min. & Milling Co. (Idaho), 141 Pacific, 566, p. 568, June, 1914.

INSOLVENCY AND REORGANIZATION—FRAUDULENT AGREEMENT WITH CREDITORS.

A contract by an insolvent corporation with the holder of its bonds to the effect that such holder could, upon default, purchase all the mining property of the corporation at a price much less than its actual value and that in consideration thereof a new company was to be organized and a stated amount of the capital stock of the new company should be issued to certain creditors of the old corporation in payment of their claim, is fraudulent and void as against the non-consenting creditors of the old corporation and ineffective to bar their resort to the property in satisfaction of their adverse demands.

Pittsmont Copper Co. *v.* O'Rourke (Montana), 141 Pacific, 849, p. 852, June, 1914.

MINING CLAIMS.

MINERAL CHARACTER OF LAND.

LANDS VALUABLE FOR MINERALS—MEANING.

Lands known to be valuable for mineral can not be acquired for any purpose other than for mining and under the mining statute, and the term "lands known to be valuable for mineral" means that there must be knowledge of the presence of mineral deposits of such quality and in such quantity as would render their extraction profitable and justify expenditures to that end; but there are vast tracts of public land in which minerals of different kinds are found, but not in such quantity as to justify expenditures in the effort to extract them, and it is not to such lands that the term "mineral" in the sense of the statute is applicable, and the term "known to be valuable" has reference to the time of purchase, and if land so purchased is not so known to be valuable at the time doubt can not be cast upon the title by any subsequent discovery of minerals however valuable.

Diamond Coal Co. *v.* United States, 233 U. S., 236, p. 240, April, 1914.

CLASSIFICATION OF MINERAL LANDS.

Where mineral surveyors are instructed to note in their returns all lands found to be of a mineral character as "mineral" and to make no notation as to lands found to be nonmineral, it can not be said that a return designating some lands as mineral and containing no notation as to others fails to classify the latter, as nonmineral, as the silence of the return in such case is as significant as the express notation in the other.

West *v.* Edward Rutledge Timber Co., 210 Fed., 189, p. 195, July, 1913.

CLASSIFICATION—MEANING OF VEIN AND LODE.

In order to determine whether lands containing a given mineral deposit are of the class subject to location and patent under the law applicable to lode claims, resort is to be had to the language of the statute rather than to definitions of the terms "vein," "lode," and "ledge" as given by geologists from a scientific viewpoint; but the statute is to be construed in the light of the prevailing and commonly known use of these terms as defined by miners as the result of their practical experience in mining, and the definitions given by the courts are not those of geologists, but are to be considered and used in the signification which they convey to the practical miner and not in the sense generally used by the scientific men.

East Tintic Min. Co., In re, 43 Land Dec., 79, p. 81, January, 1914.

GENERAL FEATURES.

MINING CLAIM—WHAT CONSTITUTES.

The rule that the term "mining claim" as used in the statute of Nevada means only an unpatented claim held under the mining laws can not be applied to mining claims held in Montana, as in the latter State a mining claim includes one held under patent as well as one held merely by location before patent.

Northern Pac. R. Co. *v.* Mjelde (Montana), 137 Pacific, 386, p. 391, December, 1913.

MINE—WHAT CONSTITUTES.

A mine is variously defined: An opening or excavation in the earth for the purpose of extracting minerals; a pit or excavation in the earth from which metallic ores or other mineral substances are taken by digging; an opening in the earth made for the purpose of taking out minerals, and in case of coal mines, commonly a worked vein; an excavation properly underground for digging out some usual product, as ore, metal, or coal, including any deposit of any material suitable for excavation and working, as a placer mine; the underground passage and workings by which the minerals are gotten together with these minerals themselves; the term "mine" when applied to coal is generally equivalent to a worked vein, for by working the vein it becomes a mine; the mode of obtaining the material and not the nature of the material itself is to be considered in order to come to a decision whether it constitutes a mine.

Northern Pac. R. Co. *v.* Mjelde (Montana), 137 Pacific, 386, p. 389, December, 1913.

EXTENT OF CLAIM.

The locator of a lode mining claim can not claim a greater length in either direction along the vein or lode than is specified in his location notice.

Swanson *v.* Koneninger (Idaho), 137 Pacific, 891, p. 892, December, 1913.

AMENDED CERTIFICATE—RELATION.

An amended certificate of a mining location intended to cure obvious defects only in the original certificate will relate back to the original, even as against intervening locations.

Gobert *v.* Butterfield (California), 136 Pacific, 516, p. 517, October, 1913.

AMENDED LOCATION.

The locator of a mining claim may amend his location if it can be done without prejudice to the rights of others.

Gobert *v.* Butterfield (California), 136 Pacific, 516, p. 517, October, 1913.

EXCESSIVE LOCATION—EFFECT.

A location in excess of the statutory limit, made in good faith and with injury to others, is voidable only as to the excess.

Gobert *v.* Butterfield (California), 136 Pacific, 516, p. 517, October, 1913.

DEPOSIT OF PURCHASE PRICE—USE BY DEPARTMENT.

The purchase price of a mining claim on application for patent must be on deposit and so remain until accepted by the Interior Department; but the department has no right to accept the purchase price of public lands and appropriate the same to the sale of any specified tract, until the purchaser has met all the conditions prescribed by law and the legal regulations made pursuant thereto which entitle him to the full legal rights to become the purchaser.

Shank *v.* Holmes (Arizona), 137 Pacific, 871, p. 875, January, 1914.

RIGHT OF LOCATOR TO WATER FROM SPRINGS.

The locator of a mining location is not entitled to the water flowing from a spring in a natural channel merely because the spring is within the exterior boundaries of his mining claim, in the absence of a proper appropriation of the water flowing from such spring.

Campbell *v.* Goldfield Consol. Water Co. (Nevada), 136 Pacific, 976, p. 978, December, 1913.

KNOWLEDGE OF VEINS OR LODES WITHIN PLACER CLAIM.

Before it can be held that veins or lodes are excluded from a placer patent it is not sufficient to show that the land does in fact contain valuable minerals, but it must be shown that at the time of the application for patent more has been discovered than the indications of minerals which would ordinarily sustain a lode location, and that it was at that time known to the placer applicant, or to the community generally, or disclosed by workings and obvious to anyone making a reasonable and fair inspection of the premises for the purpose of obtaining title, that there was rock in place bearing mineral of such extent and value as would justify expenditures for the purpose of extracting them.

Mason *v.* Washington-Butte Min. Co., 214 Fed., 32, p. 37, May, 1914.

DISCOVERY ESSENTIAL TO LOCATION.

DISCOVERY AND LOCATION ON PUBLIC DOMAIN.

The discovery on which the location of a mining claim is made must exist upon some part of the public mineral domain not already occupied and held under a prior and subsisting mining location.

Emerson *v.* Akin (Colorado Appeals), 140 Pacific, 481, April, 1914.

DISCOVERY POINT—LOCATION.

The discovery point of a lode location to make it valid must be upon free territory.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 74, January, 1914.

DISCOVERY—QUESTION OF FACT.

The question of discovery sufficient to support a lode location is one of fact, and a finding by a trial court that no discovery had been made on the claim and that the required assessment work had not been performed will not be disturbed on appeal where the evidence was conflicting, and the rule is not affected by the fact that both parties to the action were claiming the ground in dispute as being mineral.

Ebner Gold Min. Co. *v.* Alaska-Juneau Min. Co., 210 Fed., 599, p. 603, January, 1914.
See Multnomah Min. Mill, etc., Co. *v.* United States, 211 Fed., 100, January, 1914.

DISCOVERY—BURDEN OF PROOF.

An appropriate discovery of mineral is necessary to the lawful location of a placer claim, and it is not sufficient if the locator in panning obtains colors of gold and in some instances fairly good prospects of gold, but the discovery should be such as to justify a man of ordinary prudence, not necessarily a skilled miner, in the expenditure of his time and money in the development of the property; but the burden of proof is upon the Government in an action to set aside the patent alleged to have been procured by fraudulent representations as to a discovery, and the presumption that the patent was correctly issued can be overcome only by clear and convincing proof of the fraud alleged.

Multnomah Min. Mill., etc., Co. *v.* United States, 211 Fed., 100, p. 102, January, 1914.

NOTICE WITHOUT DISCOVERY—EFFECT.

The basis of location of a mining claim is discovery and the mere posting of a notice without a discovery is of no force or effect so far as rendering invalid another location covering a portion of the same ground based upon a valid discovery.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 76, January, 1914.

PRESUMPTION FROM PATENT.

Where the validity of a mining claim depends upon the priority of discovery and a patent has been issued by the Land Department it must be presumed that the department determined all facts necessary to the issuance of a valid patent, including the question of priority of discovery.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 77, January, 1914.

DISCOVERY—SUFFICIENCY.

Discovery as applied to a mining claim means the acquirement of knowledge that a vein or lode exists within the limits of the claim; and while it is not necessary that pay ore be found in order to make a valid discovery, it is necessary that the indications be of such a character that miners in the particular district would follow them in the expectation of finding ore, such as would justify them in working a claim for that purpose.

Mason *v.* Washington-Butte Min. Co., 214 Fed., 32, p. 35, May, 1914,

PROOF SUFFICIENT TO SUSTAIN.

A mineral discovery sufficient to warrant the location of a mining claim is proved where it is shown that mineral is found in such quantity that a person of ordinary prudence would be justified in the further expenditure of his labor and means with a reasonable prospect of success in developing a valuable mine.

East Tintic Min. Co., In re, 43 Land Dec., 79, January, 1914.

VALUABLE VEIN OR LODE—ELEMENTS OF VALUE.

In determining the question of the value of a vein or lode sufficient to constitute discovery the size of the vein as disclosed, the quality of mineral it carries, its proximity to working mines and location in an established mineral district, the geological conditions, the fact that similar veins in the particular locality have been successfully explored—these and other like facts would naturally be considered by a prudent man in determining whether the vein or lode discovered warrants a further expenditure.

East Tintic Min. Co., In re, 43 Land Dec., 79, p. 82, January, 1914.

ELEMENTS OF DISCOVERY.

The following elements are necessary to constitute a valid discovery on a lode mining claim: (1) A vein or lode of quartz or other rock in place; (2) the quartz or other rock in place must carry gold or other valuable mineral deposit; (3) elements 1 and 2 when taken together must be such as to warrant a prudent man in the expenditure of his time and money in an effort to develop a valuable mine.

East Tintic Min. Co., In re, 43 Land Dec., 79, p. 82, January, 1914.

MARKING BOUNDARIES.

MARKING BOUNDARIES ON THE GROUND—PURPOSE.

The object of the law in requiring the location of the mining claim to be marked upon the ground is to fix the claim to prevent floating or swinging, so that persons who in good faith are looking for unoccupied ground in the vicinity of the location may be enabled to ascertain exactly what ground has been appropriated in order to make their locations upon the residue.

Swanson *v.* Koneninger (Idaho), 137 Pacific, 891, p. 893, December, 1913.

MARKING BOUNDARIES—EFFECT AND OBLITERATION.

When a mining claim is once sufficiently marked on the ground and all necessary location acts are performed, the locator is vested with a right which can not be divested by a subsequent obliteration of the marks or removal of the stakes, without his fault, and the fact that the original stakes can not in later years be found raises no presumption against the validity of the original marking.

Gobert *v.* Butterfield (California), 136 Pacific, 516, p. 517, October, 1913.

TIME OF MARKING BOUNDARIES.

The boundaries of a mining claim may be marked at any time prior to the acquisition of an intervening right, regardless as to whether the time within which the marking was made is reasonable or otherwise.

Gobert *v.* Butterfield (California), 136 Pacific, 516, p. 517, October, 1913.

SWINGING CLAIMS.

SHIFTING LINES.

It is contrary to the policy and spirit of the mining laws to permit a mining claim of excessive size to be staked and then afford the opportunity for the stakes to be shifted at the locator's pleasure and the claim swung so as to include ground proved to be rich in mineral through the development of other ore bodies.

Swanson *v.* Koneninger (Idaho), 137 Pacific, 891, p. 893, December, 1913.

Before patent a lode locator may shift his lines or float his location on the public domain if he does not interfere with the rights of others.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 79, January, 1914.

LOCATION NOTICE AND CERTIFICATE.

CONTENTS AND SUFFICIENCY—RECORD.

A record of a certificate of location which recites the citizenship of the locators, the fact of discovery, and the fact that the location has been marked upon the ground so that the boundaries can be readily traced is not evidence of any of these facts in any of the States or Territories for the reason that no such facts are required to be stated in any of the statutory notices.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 76, January, 1914.

LOCATION NOTICE—SUFFICIENCY.

A location notice or declaratory statement as it is sometimes called is not required to contain a description of the mining claim by metes and bounds, but the statute does require that, taking the discovery as the initial point, the boundaries be so definite and certain as that they can be readily traced, and the notice or declaratory statement must contain directions, which, taken with the marking, will enable a person of reasonable intelligence to find the claim and run its lines; but while neither mathematical precision as to measurements nor technical accuracy of expression is expected, yet the degree of accuracy that is required is indicated by the fact that the locator, after his discovery, has 30 days in which to definitely ascertain the course of the vein or lode and mark its boundaries, and 30 days more in which to file his notice or declaratory statement describing the claim so that it can be identified.

Swanson *v.* Koneninger (Idaho), 137 Pacific, 891, p. 893, December, 1913.

SUFFICIENCY.

It can not be said as a matter of law that a notice of the location of a mining claim is insufficient where the notice was written on a piece of white paper and placed on a stick leaning up against the side of a cut on the surface rock, and another rock put on top of the paper so that it would not blow away, the paper being large enough to show under the rock, but the writing itself was not exposed.

Emerson *v.* Akin (Colorado Appeals), 140 Pacific, 481, p. 482, April, 1914.

LOCATION NOTICE—INSUFFICIENCY.

That degree of accuracy required in a location notice or declaratory statement is not met if the description given is so erroneous as to be delusive and misleading, as when the declaratory statement and the markings upon the ground do not even approximately agree as to the general shape of the claim or as to any point, direction, or distance.

Swanson *v.* Koneninger (Idaho), 137 Pacific, 891, p. 893, December, 1913.

CONFLICT BETWEEN NOTICE AND BOUNDARIES.

In case of a conflict between the location notice of a lode claim and the boundaries of the claim as marked by the stakes, the rule that the stakes control applies only so far as there is no substantial variance between such stakes and the notice of location; but where the course and distance are not with certainty defined by monuments or stakes the clause in the location notice must govern. Where there is doubt as to the monuments, there can be no reason for the rule that the monuments should prevail.

Swanson *v.* Koneninger (Idaho), 137 Pacific, 891, p. 892, December, 1913.

CERTIFICATE OF LOCATION—PRESUMPTIVE EVIDENCE.

Where mining claims have been transferred and have stood unchallenged for years and have been developed by successive owners, a certificate of location in due form is presumptive evidence of discovery and of a valid location; but in the absence of grounds of such presumptive evidence a location notice is, when recorded, prima facie only of what the State requires it to contain, and which is therein sufficiently set forth.

Thomas *v.* South Butte Min. Co., 211 Fed., 105, p. 107, February, 1914.

LOCATION CERTIFICATE—CONTENTS.

Section 2324 of the Revised Statutes of the United States requires that a certificate of the location of a mining claim shall contain the names of the locators, the date of location, and such a description of the claim by reference to some natural object or permanent monuments as will identify it, but such a certificate is not proof of discovery or the existence of a vein or lode that would justify exploitation, and especially so where there is no proof that the claim was ever developed.

Thomas *v.* South Butte Min. Co., 211 Fed., 105, p. 108, February, 1914.

MINERAL SURVEYOR—QUALIFICATIONS AND DUTIES.

DEPUTY MINERAL SURVEYOR DISQUALIFIED.

A deputy mineral surveyor is an officer or employee of the general land office within the scope of section 452 of the Revised Statutes of the United States and is disqualified and prohibited from directly or indirectly purchasing or becoming interested in the purchase of public lands.

United States *v.* Havenor, 209 Fed., 988, p. 989, November, 1913.

DUTY TO NOTE CONFLICT AREA.

It is the duty of a deputy mineral surveyor to set forth in his field notes the exclusions of any conflict area in surveying a mining claim and to designate the claim or claims in favor of which such exclusion is made, and it is not to be presumed, in the absence of a showing to the contrary, that the application for patent or the public notice was in conflict with the exclusion made in the field notes of the deputy mineral surveyor.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 75, January, 1914.

PLAT AND FIELD NOTES—APPROVAL.

The plat and field notes of a deputy mineral surveyor must have the approval of the United States surveyor general before transmission to the General Land Office; and when the field notes of a deputy mineral surveyor are approved by the surveyor general, and such plat and field notes show an exclusion made by the officials of the Government upon whom the duty is imposed of making the same, and when patent issues and reference is made to such field notes, the exclusions therein mentioned become the exclusions of the Government itself, and it is immaterial at whose instance they were made, even if made at the suggestion of the applicant himself.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 76, January, 1914.

DESCRIPTION OF CLAIM.

REFERENCE TO PLAT AND FIELD NOTES—EFFECT.

A reference in a patent for a mining claim to the official plat and survey makes such plat and field notes of such survey a part of the description granted, the same as if incorporated at length in the patent.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 76, January, 1914.

REGULATIONS OF GENERAL LAND OFFICE.

The rules and regulations of the General Land Office in relation to mining claims have the force and effect of law and may require the description of a mining claim to show definitely the portions intended to be included and may require that the survey of contiguous locations shall distinguish the several locations and exhibit the boundaries of each and state the area of each location and also the area in conflict with any intersecting survey or claim.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 75, January, 1914.

SURVEY SUFFICIENT FOR DIFFERENT APPLICATIONS.

The mere canceling of the entry upon an application for patent for mining claim, and in which the official survey was made a part, in no manner affects the plat and field notes of the survey or prohibits their use or a copy thereof in a subsequent application for a patent for the same claim.

Shank *v.* Holmes (Arizona), 137 Pacific, 871, p. 874, January, 1914.

ASSESSMENT WORK.

ASSESSMENT WORK—CONSIDERATION.

Money advanced by a bank at the request of the managing officers of a mining corporation for the payment of assessment work is a sufficient consideration for the execution by the mining corporation of a note secured by a mortgage on an unpatented claim.

Miller *v.* Del Rio Min. & Mill. Co. (Idaho), 136 Pacific, 448, p. 450, November, 1913.

RESUMPTION OF WORK—EFFECT.

The locator of a mining claim in Alaska who has failed to perform the annual assessment work as required by the act of March 2, 1907 (34 Stat., 1243), can not protect his claim and save his rights by a resumption of the work prior to the intervention of other parties.

Ebner Gold Min. Co. *v.* Alaska-Juneau Min. Co., 210 Fed., 599, p. 604, January, 1914.

PROOF OF PERFORMANCE.

Under section 3211 of the Revised Codes of Montana the affidavit of the performance of the annual assessment work upon lode mining claims is prima facie evidence of the performance of such assessment work, but when such prima facie evidence is met and overcome by positive evidence that the labor was not performed it then devolves upon the locator or owner to show by evidence of a positive and affirmative nature other than the affidavit that the work had actually been performed; but the mere proof that the locator or owner had actually paid $100 for the performance of such assessment work is not sufficient evidence that the work was actually done where the proof showed that the work was not done, as in such case the question is not whether the money was paid for the work, or whether the locator honestly believed the work was done, but whether the work was actually performed on the mining claim, and the statute requiring the work is mandatory.

Dickens-West Min. Co. *v.* Crescent Min. & Milling Co. (Idaho), 141 Pacific, 566, p. 568, June, 1914.

CONSTRUCTION OF ROAD.

Labor performed by the owner of a mining claim in constructing a wagon road thereto for the purpose of better developing and operating his mine and for the purpose of aiding in the conduct of mining operations on the particular claim to which it is sought to be accredited, the value whereof is duly certified by the surveyor general, may be accredited as assessment work or as development work required as a prerequisite to the issuance of a patent.

Tacoma & Roche Harbor Lime Co., In re, 43 Land Dec., 128, p. 132, February, 1914

MINERS REGULATING ASSESSMENT WORK.

Section 2324 of the Revised Statutes of the United States permits miners of each mining district to make regulations not in conflict with the United States statutes governing assessment work on mining claims.

Tacoma & Roche Harbor Lime Co., In re, 43 Land Dec., 128, p. 131, February, 1914.

CERTIFICATE OF SURVEYOR GENERAL—BASIS OF INFORMATION.

The surveyor general may derive his information upon which to base his certificate as to the value of labor expended or improvements made upon a mining claim from the deputy mineral surveyor who made the actual survey and examination upon the premises, and such deputy should specify with particularity and full detail the character and extent of such improvements, and in any case further or other evidence may be required.

Sheldon, In re, 43 Land Dec., 152, p. 155, February, 1914.

IMPROVEMENTS.

TIME OF MAKING—PROPER CREDITS.

No part of the value of permanent or immovable improvements upon a mining claim made long prior to the location thereof by the claimant under a previous location embracing the same ground, solely to improve and develop the entire claim, can be accredited to the later claim toward meeting the statutory requirement as to patent expenditures.

Sheldon, In re, 43 Land Dec., 152, p. 156, February, 1914.

CERTIFICATE OF SURVEYOR GENERAL—CONCLUSIVENESS.

A certificate of the surveyor general to the effect that $500 worth of labor has been expended or improvements made upon or for the benefit of the several locations by the owners or their grantors, the improvements consisting of two discovery shafts, two discovery cuts, five cuts, nine shafts, and a drift valued at $2,855, as required by section 2325 of the Revised Statutes of the United States, is not conclusive upon the Land Department as to the improvements made, but the department may wholly disregard such certificate and require further showing as to the improvements made by the applicant.

Sheldon, In re, 43 Land Dec., 152, pp. 154–156, February, 1914.

CERTIFICATE OF SURVEYOR GENERAL.

Section 2325 of the Revised Statutes of the United States requires a certificate by the surveyor general, in support of an application for a patent to a mining claim, to the effect that $500 worth of labor has been expended or improvements made upon the mining claim sought to be patented.

Tacoma & Roche Harbor Lime Co., In re, 43 Land Dec., 128, p. 131, February, 1914.

LOCAL LAWS—REGULATIONS IN MINING DISTRICTS.

The statute of Washington (sec. 7371, Remington and Ballinger's Annotated Codes, 1910) gives a mining district the power to make road building to mining claims applicable as assessment work or improvements upon the claims, and directs specifically how such regulations may be enacted, and when and how such road building shall be done, and provides also that a receipt given for such work shall be prima facie evidence of the improvement; and a locator of a mining claim claiming the benefits of the provisions of this statute must show that his mining claim lies within the organized district and that such mining district has complied with the requirements of the State statute.

Tacoma & Roche Harbor Lime Co., In re, 43 Land Dec., 128, p. 131, February, 1914.

EXPENDITURES FOR DRILL HOLES.

Expenditures made upon drill holes placed upon a lode mining claim in good faith with a view to prospect the claim, or in order to secure data upon which further development work may be performed, are available toward meeting the statutory provision requiring an expenditure of $500 as a basis of patent, as to all of the claims of a group situated in close proximity to the common improvement.

East Tintic Min. Co., In re, 43 Land Dec., 79, p. 83, January, 1914.

ABANDONMENT.

WHAT CONSTITUTES—INTENTION AND ACT.

Abandonment as applied to mining claims held by location merely, takes place only when the locator voluntarily leaves his claim to be appropriated by the next comer without any intention to retake or reclaim it, and regardless of what may become of it in the future.

Shank *v.* Holmes (Arizona), 137 Pacific, 871, p. 875, January, 1914.

Abandonment of a mining claim is a matter of intention, and when any part of a mining claim is in good faith abandoned by the owner the title of the part thus abandoned reverts to the Government, and abandonment in such case may be proved by the acts of the original owner as well as by his words and statements; and this question applies especially where there was no fraudulent purpose in the abandonment.

Emerson *v.* Akin (Colorado Appeals), 140 Pacific, 481, p. 482, April, 1914.

FORFEITURE.

WHAT CONSTITUTES.

A forfeiture of a mining claim takes place by operation of law without regard to the intention of the locator whenever he neglects to preserve his right by complying with the conditions imposed by law, such as making the required annual expenditures upon the claim within the statutory period; and the difference between abandonment and forfeiture is that the former involves an inquiry of fact as to the intention as well as the act, while the latter is determined by the answer to the question, Has the required expenditure been made as the law commands?

Shank *v.* Holmes (Arizona), 137 Pacific, 871, p. 875, January, 1914.

RELOCATION.

RELOCATION OF ABANDONED CLAIMS.

The locator of a mining claim on the public domain may abandon such claim, or he may abandon a part thereof and subsequently make a valid relocation including the whole or a part of such abandoned claim, where the rights of third persons are not invaded and where the abandonment was not from improper motive, such as escaping annual assessment work.

Emerson *v.* Akin (Colorado Appeals), 140 Pacific, 481, p. 482, April, 1914.

POSSESSORY RIGHTS—PROTECTION.

EFFECT OF TRESPASS.

A locator of a lode mining claim can not be deprived of his possessory or inchoate rights by the tortious acts of another, nor can an intruder and trespasser initiate any rights that will defeat those of a prior discoverer.

Gobert *v.* Butterfield (California), 136 Pacific, 516, p. 517, October, 1913.

DISCOVERY AS BASIS OF RIGHT.

In an action to determine the title and right of possession to a lode mining claim, and where it is contended on the part of the defendant that there had been no sufficient discovery of mineral on which to make a mining location as required by the statute, it is proper to admit testimony tending to show that the discovery shaft of the adverse claimant did not, at the date of the record of its certificate, disclose a well-defined crevice vein or lode, but in fact disclosed no mineral of any kind whatsoever therein at a depth of 10 feet from the lowest part of the rim at the surface, and to show the effect and value of assays made; nor is it error to permit the jury trying the case to view the premises, under instructions from the court to the effect that the evidence must be considered solely on the question as to whether there was mineral-bearing rock found in the discovery shaft.

Specie Payment Gold Min. Co. *v.* Kirk (Colorado), 139 Pacific, 21, March, 1914.

POSSESSORY ACTION OF LOCATOR TO PROTECT RIGHTS.

A person in possession of a portion of the public domain and claiming title thereto under a placer location on oil lands may maintain ejectment against a mere intruder or trespasser entering upon such possession without right or color of title, though the plaintiff's location may be invalid.

Little Sespe Consolidated Oil Co. *v.* Bacigalupi (California), 139 Pacific, 802, p. 803, March, 1914.

INTRUDER ACQUIRES NO RIGHTS.

A wrongful intrusion upon a portion of the public land held by another as a mining claim, and after discovery of oil thereon, gives no right whatever to the intruder and constitutes him a naked trespasser, and he is in no position to raise any issue whatever upon the question of title under which the oil claimant holds the possession of his claim; an entry on such a claim in order to initiate any rights must be peaceable and in good faith.

Little Sespe Consolidated Oil Co. *v.* Bacigalupi (California), 139 Pacific, 802, p. 804, March, 1914.

CONDITIONS—PERFORMANCE OF ASSESSMENT WORK.

The locator of a mining claim has the exclusive right of possession of all the surface included within the exterior limits of his claim so long as he makes the improvements or does the annual assessment work required by section 2324 of the Revised Statutes of the United States.

El Paso Brick Co. *v.* McKnight, 233 U. S., 250, p. 256, April, 1914.

ACQUIRING FEE-SIMPLE TITLE.

The defeasible possessory title held by the locator of a mining claim on compliance with the United States statutes may, by payment of the purchase price fixed by statute (sec. 2325, R. S.), be converted into a fee simple.

El Paso Brick Co. *v.* McKnight, 233 U. S., 250, p. 256, April, 1914.

EFFECT OF LOCATION—ACQUIRING ADVERSE RIGHTS.

Mineral ground covered by a valid location is, during the life of the location, segregated and not open to location by another, and until such location is terminated by abandonment or forfeiture no right or claim to the property can be acquired by an adverse entry thereon with a view to the relocation of the same ground.

Mason *v.* Washington-Butte Min. Co., 214 Fed., 32, p. 35, May, 1914.

ADVERSE CLAIMS.

FAILURE TO FILE—EFFECT.

A failure to file an adverse claim within the time fixed by law operates as a waiver of all rights that were the proper subject of such a claim, and the issuance of a patent on a regular application after due notice is equivalent to a determination by the United States in an adversary proceeding, to which the owner of such adverse right is in contemplation of law a party, that the applicant's and patentee's rights were superior and those which might have been asserted by the holder of the adverse title were valueless; and in the absence of such adverse claim all matters which might have been tried under the adverse proceedings are treated as adjudicated in favor of the applicant, and all controversies touching the same are held as fully settled and disposed of as though judgment had been regularly rendered in an action on the adverse claim.

Round Mountain Min. Co., *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 73, January, 1914.

FAILURE TO FILE—SURFACE CONFLICT.

Where there is any surface conflict whatever of mining claims and there is a failure to adverse on proper application and notice, after patent issues to the applicant, the question of priority of title is conclusively determined in favor of the patentee.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 73, January, 1914.

FAILURE TO FILE—RIGHT TO PROTEST.

A failure to assert an adverse claim or right will not estop an advance claimant from protesting and bringing to the notice of the department any facts that tend to show noncompliance by the applicant with the requirements of the law.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 73, January, 1914.

FAILURE TO ADVERSE—EFFECT ON RIGHTS.

A person interested in a mining claim whose rights are affected by an application for a patent for the same or for a conflicting claim who fails to file an adverse claim or fails to institute adverse proceedings after filing an adverse claim, or fails to protest in the Land Office against the issuance of a patent, can not, after the issuance of a patent to the applicant, be heard to contest a question of fact upon which the patent is based.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific , 71, p. 77, January, 1914.

COMMENCEMENT OF PROCEEDINGS—EFFECT OF JUDGMENT.

Section 2326 of the United States Revised Statutes requires an adverse claimant to commence proceedings in a court of competent jurisdiction to determine the question of the right of possession, and declares that the failure to do so shall be a waiver of any adverse claim, and also requires that after judgment the whole proceedings and the judgment shall be certified to the Land Office, and a patent shall issue thereon for the claim or such portion thereof as the applicant shall appear from the judgment to be entitled to.

Mason *v.* **Washington-Butte Min. Co., 214 Fed., 32, 35, May, 1914.**

JURISDICTION OF COURT—QUESTIONS DETERMINED.

Section 2326 of the United States Revised Statutes gives to a court of competent jurisdiction the power to determine the right of possession between adverse claimants, and the determination of such question necessarily involves not only the question which of the adverse claimants was prior in time in making location, and whether the location was made in compliance with the law, but also whether the land occupied and covered by the location was subject to location in the manner in which it was attempted to be acquired.

Mason *v.* **Washington-Butte Min. Co., 214 Fed., 32, p. 36, May, 1914.**

FORCE AND EFFECT OF JUDGMENT OF COURT.

The judgment of a court of competent jurisdiction on an adverse claim under section 2326 of the United States Revised Statutes governs the action of the officers of the Land Department in determining which of the claimants shall have a patent and enables the Land Department without further investigation to issue a patent for the land.

Mason *v.* Washington-Butte Min. Co., 214 Fed., 32, p. 36, May, 1914.

WAIVER.

There is no difference in legal effect between waiving an adverse claim on the part of an adverse claimant by a transfer to the applicant of the interests of such adverse claimant by positive action, or the transfer of such interests by operation of law; and the latter effect results where the defendant to a proceedings brought by the adverse claimant concedes the overlapping as alleged by the plaintiff, the adverse claimant, but establishes by positive proof that the alleged overlapping ground, claimed by the adverse claimant, was in law the property of the defendent, the original applicant for patent, as in such case the plaintiff's apparent cause of action ceases to exist, and there being in fact no conflict of interest, and the plaintiff having no cause of action, a judgment dismissing the plaintiff's action operates as a determination in favor of the defendant and is in legal effect a waiver of the adverse claim.

Cuenin *v.* Chloride Min. & Prospecting Co. (Colorado), 141 Pacific, 453, p. 464, June, 1914.

Section 2326 of the United States Revised Statutes provides that where an adverse claim is filed during the period of publication all proceedings, except the publication of notice and making and filing of the affidavit thereof, shall be stayed until the controversy is determined by a court of competent jurisdiction, or the adverse claim is waived; but the settlement of the controversy or the waiver of the adverse claim does nor necessarily depend upon a verdict of a jury, as the claim may be waived by failure to file it within the statutory period, or by a voluntary dismissal of it in the Land Office, or by a transfer to the applicant of the interests of the adverse claimant, or by dismissal of the action instituted in support of such adverse claim.

Cuenin *v.* Chloride Min. & Prospecting Co. (Colorado), 141 Pacific, 463, p. 464, June, 1914.

PLACER CLAIMS.

SUFFICIENCY OF DISCOVERY—FRAUDULENT ENTRY.

In an action by the United States to have canceled a patent issued for a placer mining claim, the finding of the court will be sustained where no sufficient discovery of mineral was found to support the claim, and where the facts tend to show that the land was entered for the fraudulent purpose of securing control of valuable water power and incidentally to use the lands covered by the placer claim for raising fruits, and where it was shown that for a period of several years no mining was actually done on the claim, and that after the issuance of the patent all exploitation of the claim as placer ground was abandoned and the articles of incorporation of the mining company were amended so as to give the mining company other powers than that of mining, clearly indicating that the original purpose of location was not a mining claim but the development of water power, the distribution of water for irrigation, and the manufacture of electricity.

Multnomah Min. Mill., etc., Co. *v.* United States, 211 Fed., 100, p. 101, January, 1914.

LOCATION OF LODE WITHIN PLACER LIMITS.

The fact that a mineral lode location was made within the limits of a placer mining claim is not of itself proof that the ground so located contained a vein or lode within the meaning of section 2333 of the Revised Statutes of the United States; nor is it proof that the alleged vein or lode was known to exist at the time of the placer location; and a lode or vein known to exist within the limits of a placer location so as to exclude it from the placer patent must be one which contains mineral to such extent and value as to justify expenditures for the purpose of extracting it.

Thomas *v.* South Butte Min. Co., 211 Fed., 105, p. 107, February, 1914.

CONVEYANCE OF VEINS OR LODES.

A patent to a placer claim conveys all the mineral therein including veins or lodes not known to exist at the time of the application for patent, and the introduction in evidence of such a patent establishes prima facie title to all the lands described therein including all ores and minerals within the boundaries thereof.

Thomas *v.* South Butte Min. Co., 211 Fed, 105, p. 107, February, 1914.

ADJUDICATION BY COURT—EFFECT ON LODE LOCATION.

A judgment in favor of a placer applicant in adverse proceedings instituted by the locator of a lode claim establishes as between the parties that the lode location was not a valid subsisting location such as was efficient to segregate the land covered thereby from the public domain and to exclude the same from the land covered by the placer claim; but the Government is not bound by such a judgment further than it has declared that it will accept such a judgment as conclusive of the right of possession as between contending claimants, and such a judgment goes no further than to end the contest between the parties and determine the right of possession, leaving the applicant to make the proof required by law to entitle him to a patent. But the judgment does not determine that there were not, within the ground covered by the placer claim, veins or lodes known to exist at the time of the application for the patent, nor does it settle the question of the validity of subsequent locations, the rights whereof depend on whether at the time of the application for placer patent there were known veins and lodes such as to be excluded from the patent.

Mason *v.* Washington-Butte Min. Co., 214 Fed., 32, p. 36, May, 1914.

COAL LOCATIONS.

PURCHASE—PRICE AND QUANTITY.

Coal lands within railroad limits must be sold for $20 an acre, and a coal company can not purchase directly or indirectly through others more than 320 acres unless it expended $5,000 in opening and improving a mine, and in that event the maximum is 640 acres.

Diamond Coal Co. *v.* United States, 233 U. S., 236, p. 241, April, 1914.

COAL CHARACTER—CHARACTER OF ADJACENT LANDS.

There is no fixed rule that lands become valuable for coal only through the discovery of coal within their boundaries; but on the contrary they may and often do become valuable for coal through adjacent discoveries and other surroundings and external conditions; and in an application to purchase lands in coal regions any evidence logically relevant to the issue is admissible, due regard being had to the time to which it must relate.

Diamond Coal Co. *v.* United States, 233 U. S., 236, p. 249, April, 1914.

RESTRICTED PATENT.

Where upon a nonmineral entry it is shown by ex parte affidavits that the land is coal in character and the entryman declines to take a restricted patent under the act of March 3, 1909 (35 Stat., 844), the character of the land should not be adjudicated upon the ex parte affidavits, but a hearing should be ordered with respect to the character of the land.

Hindman, In re, 43 Land Dec., 191, p. 192, March, 1914.

PATENTS.

JURISDICTION OF LAND DEPARTMENT.

When a patent for a mining claim is issued the functions of the Land Department terminate, as this is the culmination of the proceeding in rem and the final judgment of the tribunal specially charged with passing the Government title, and with the title passes all authority or control of the executive department over the land and over the title which it conveys.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 73, January, 1914.

The Land Department is a tribunal appointed by Congress to decide certain questions relating to the public lands, and its decisions upon matters of fact cognizable by it, in the absence of fraud or imposition, is conclusive, and the rule relates to its jurisdiction over mining claims.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 73, January, 1914.

APPLICATION FOR PATENT—CANCELLATION OF ENTRY—EFFECT.

The decision of the Land Office in canceling an entry on an application for a patent for a mining claim is binding upon the courts and is conclusive that the entryman failed to meet all the statutory requirements, and adjudicates the fact that the entryman obtained no title by his entry and the cancellation deprives him of the ability to claim any right under his receipt; and the mere fact that the amount of money sufficient to purchase the mining claim remains on deposit after the entry was canceled gives the applicant no equitable rights to the ground he desired to purchase with the money, nor would the fact that the applicant procured an official survey to be made of the ground alone create any title thereto in the applicant.

Shank *v.* Holmes (Arizona), 137 Pacific, 871, p. 875. January, 1914.

APPLICATION—PUBLICATION OF NOTICE.

On an application for a patent for a mining claim the applicant must give 60 days' notice in order to afford all persons having any adverse claims an opportunity to be heard, and the notice is threefold and must be given by publication in the nearest newspaper, designated by the register, by posting on the land itself, and in the land office, and proof of posting on the claim must be proved by the affidavit of two persons before an officer residing within the land district. In the absence of an adverse claim filed within the statutory period it shall be assumed that the applicant is entitled to patent upon the payment of the proper price and that no adverse claim exists.

El Paso Brick Co. *v.* McKnight, 233 U. S., 250, p. 256, April, 1914.

APPLICATION—PAYMENT OF PRICE—EFFECT AND RIGHTS.

Where the locator of a mining claim makes application for patent, posts and publishes the notices as required, makes proper proof thereof, and pays the purchase price of the land, he is entitled to a final receipt, and where such receipt is issued the entry by the local land officer is in the nature of judgment in rem and determines the validity of the original location and that everything necessary to keep it in force, including the annual assessment work, has been done and that no adverse claim exists and that the applicant is entitled to a patent; and in such case the applicant holds under an equitable title and is to be treated as though patent had been actually delivered.

El Paso Brick Co. *v.* McKnight, 233 U. S., 250, p. 257, April, 1914.

APPLICATION—INSUFFICIENT PROOF—CANCELLATION OF ENTRY.

An entry duly made on an application for patent for a mining claim where the applicant shows due compliance with all the statutory requirements, including the performance of assessment work and the proper publication and posting of notice, the payment of the price, and issue of the final receipt, can not be canceled by the Land Department and the claim made subject to relocation solely for the reason that the affidavit in proof of posting the notice on the claim was made before an officer residing outside of the land district, as such irregularity did not render the patent proceedings void and the Land Department acquired jurisdiction upon giving notice of publication in the newspaper, by posting in the land office, and by posting on the land itself, and the irregularity in complying with the mere directory provision as to the proof, could be cured, and on being cured the patent could issue, and the cancellation of the entry being based on an error of law, did not operate to deprive the applicant of its property in the mining claim, nor did the fact that the applicant instituted new proceedings in order to secure patent, destroy the rights with which he had become invested by full compliance with the requirements of the statute.

El Paso Brick Co. *v.* McKnight, 233 U. S., 250, p. 238, April, 1914.

CANCELLATION OF ENTRY—RECEIVER'S RECEIPT.

The cancellation of an entry or of the receiver's receipt is, like its issuance, a mere incident in the proceedings prescribed for procuring title from the Government; and while the receiver's receipt when in force is evidence of compliance with preliminary patent conditions, yet its revocation or cancellation and nothing more, of itself, does not evidence either the forfeiture or relinquishment of the location made by the applicant, and it has no necessary connection either with the segregation of the land from the public domain or its restoration thereto.

Shank *v.* Holmes (Arizona), 137 Pacific, 871, p. 875, January, 1914.

SECOND APPLICATION AFTER CANCELLATION OF ENTRY.

The locator of a mining claim who makes a second application for patent after a cancellation of the entry on his former application thereby accepts and acquiesces in the decision of the General Land Office canceling his former entry, and from the date of such cancellation the applicant's right to the possession of the ground located depends upon the location and the rights arising therefrom under the laws pertaining thereto, without reference to the former application and entry.

Shank *v.* Holmes (Arizona), 137 Pacific, 871, p. 875, January, 1914.

EFFECT AND CONCLUSIVENESS.

A patent for a mining claim is the highest evidence of title and is conclusive against the Government and all persons claiming under junior patents or titles, until set aside and annulled, and it is not open to collateral attack.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 73, January, 1914.

EFFECT—SECOND GRANT.

The Government having issued a patent for a mining claim can not by the authority of its own officers invalidate such patent by the issuing of a second one for the same property.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 73, January, 1914.

EFFECT AND CONCLUSIVENESS.

A patent for a mining claim is conclusive evidence that all antecedent steps necessary to its issuance have been properly and legally taken and is likewise conclusive evidence of the citizenship and qualification of the patentee and that the matters which might have been the subject of an adverse claim have been conclusively adjudicated in favor of the patentee.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 73, January, 1914.

EFFECT IN CASE OF SURFACE CONFLICT.

The issuance by the Government of a patent for a mining claim, on proper application and after due notice, conclusively determines, as against everyone whose surface lines conflict with the claim embraced in the application, the priority of the location described in the application over all other locations, and confers upon the patentees and their successors in interest the entire surface of the claim, as against every other one whose surface lines conflict with that of the claim described, together with the extralateral rights conferred by section 2322 of the Revised Statutes; but conflicts in respect to extralateral rights growing out of locations whose surfaces do not conflict, and which are therefore beyond the purview of the proceedings in the Land Department, are matters solely for the determination of the courts when subsequently arising.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 73, January, 1914.

GROUPED CLAIMS IN SINGLE PATENT—CONFLICT AREAS.

On application for patent for a group of several mining claims the Land Department necessarily adjudicates and determines the priorities in case of surface conflict, and does not leave such question for subsequent determination by courts, as it was not the intention of Congress or the Land Department to leave such questions unsettled after patent, as evidenced by the rule requiring the field notes of the mineral surveyor to state the conflict in connection with the location from which the conflicting area is excluded; and a patent to a group of mining claims does not merely describe the exterior boundaries of the land which is embraced by the group, but describes each location and each embraces a separate portion of the grant to the exclusion of every other claim, the same as if a separate patent issued for each particular location.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 77, January, 1914.

EFFECT ON CONFLICT GROUND—PRESUMPTION.

When a patent for a mining claim shows a conflict but fails to mention any exclusion of conflict area, although the total area described shows that an exclusion had in fact been made, it must be presumed that the exclusion was made in favor of the claim the discovery point of which lay within the conflict territory as this is necessary to its validity.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 74, January, 1914.

NONCONTIGUOUS CLAIMS.

The Land Office now issues patents for noncontiguous pieces of ground embraced in the same mining claim, though separated by a prior location, and the granting of such a patent does not necessarily determine the invalidity of such intervening location.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 77, January, 1914.

COLLATERAL ATTACK.

A patent to a mining claim may be collaterally impeached in any action and its operation as a conveyance defeated by showing that the department had no jusridiction to dispose of the land, either by proof that the law did not provide for selling such lands, or that they had been reserved from sale, or dedicated to special service or had been previously conveyed to them.

Round Mountain Min. Co. *v.* Round Mountain Sphinx Min. Co. (Nevada), 138 Pacific, 71, p. 73, January, 1914.

ACTION TO CANCEL—BURDEN OF PROOF.

The respect due to a patent for mining claim and the presumption that all the preceding steps required by law were duly observed, and the obvious necessity for stability in titles resting upon patents, require that in a suit to cancel any such patent the Government shall bear the burden of proof and shall sustain it by that class of evidence which commands respect and that amount of it which produces conviction.

Diamond Coal Co. *v.* United States, 233 U. S., 236, p. 239, April, 1914.

FRAUDULENT PROCUREMENT—CANCELLATION.

A patent to a mining claim secured by fraudulent practices, although not void or subject to collateral attack, is nevertheless voidable and may be annulled in a suit by the United States Government against the patentee or a purchaser with notice of the fraud.

Diamond Coal Co. *v.* United States, 233 U. S., 236, p. 239, April, 1914.

FRAUDULENT REPRESENTATION AS TO MINERAL CHARACTER OF LAND—CANCELLATION.

To justify the annulment of a homestead patent as wrongfully covering mineral land, it must be made to appear that at the time of the proceedings which resulted in the patent the land was known to be valuable for mineral, and this means that it must be made to appear that the known conditions at the time of such proceedings were plainly such as to engender the belief that the land contained deposits of such quality and in such quantity as would render their extraction profitable and justify expenditures to that end; and the inquiry must be directed to the situation at that time and if the proofs offered were not false then, they can not be condemned nor the good faith of the applicant impugned, by reason of any subsequent changes in the conditions.

Diamond Coal Co. *v.* United States, 233 U. S., 236, p. 239, April, 1914.

CANCELLATION OF PATENT—FRAUD—PROOF.

In an action to cancel a patent to coal lands on the ground of fraud it is proper to show that for many years the district in which the lands were situated had been known to contain coal and that an outcrop of coal on adjacent lands had been opened at different places disclosing a coal bed from 6 to 14 feet in thickness containing coal of superior quality and recognized commercial value, and that the dip of the coal vein was in the direction of the land in controversy, the farthest section of the land being about a mile and a half away from such outcrops of coal, and unless valuable for coal the lands were not worth more than $1.25 an acre, being arid, sagebrush land, some 7,000 feet above sea level, without irrigation, and of little value for agriculture; it is also proper to show as evidencing the good faith of the mining corporation seeking to obtain title, that the corporation had by the payment of large sums procured its officers and employees to make entries of different parts of the land, the entries subsequently being canceled and the same person immediately applied to enter the lands under soldiers' additional rights, and that the mining corporation had in its various dealings with its employees and dummies expended at least $10 per acre in its attempt to acquire lands and that it had from its operations of lands in the immediate vicinity in the three years preceding obtained about 885,000 tons of coal.

Diamond Coal Co. *v.* United States, 233 U. S., 236, p. 241-248, April, 1914.

CANCELLATION OF ENTRY ERRONEOUSLY ALLOWED—REPAYMENT.

Section 1 of the act of March 26, 1908 (35 Stat., 48), provides that where purchase money and commissions paid under any public land law have been paid into the Treasury under any application for location or entry, such purchase money shall be repaid to the applicant in all cases where the application, entry, or proof has been rejected; and in the absence of fraud, under this act payment made may be refunded to an applicant, though repayment had been denied under the act of June 16, 1880 (21 Stat., 287), as the purpose of the later act was to return to disappointed purchasers of public lands their purchase money in all cases where they failed to acquire title and had been guilty of no fraud in connection with their applications to purchase.

Cumberland Min. & Smelting Co., In re, 43 Land Dec., 183, p. 184, March, 1914.

PATENT INCLUDES VEINS OR LODES.

A patent to a placer claim conveys all minerals within the claim including veins or lodes not known to exist at the time of the application for the patent, and such a patent establishes prima facia title to all the land therein described and all ores and minerals lying within the boundaries thereof.

Mason *v.* Washington-Butte Min. Co., 214 Fed., 32, p. 34, May, 1914.

STATUTES RELATING TO MINING OPERATIONS.

CONSTRUCTION AND VALIDITY.

PURPOSE OF STATUTE—PROTECTION OF MINERS.

Section 1016, of the Alabama Code of 1907 requiring the operator of every coal mine to maintain ample means of ventilation is designed for the purpose of protecting human life and should be so construed as to effectuate the legislative intent, and this section should not be so whittled down as to make it the imperative duty of the operator to supply only the means, but should be so construed as to require that the operator keep his mine harmless from noxious gases generated therein.

Walker *v.* Birmingham Coal & Iron Co. (Alabama), 63 Southern, 1012, p. 1013, December, 1913.

PURPOSE OF STATUTE—PROTECTION OF INFANTS.

In 1897 the legislature of Alabama passed an act entitled "An act to regulate the mining of coal in Alabama," and section 27 of the act provides that no woman shall be employed to work or labor in or about the mines in the State, or any boy under the age of 12 years be so employed; and the Code of 1907 (sec. 1035) provides that no woman or boy under the age of 14 years shall be employed to work or labor in or about any mine in the State; and this change in the legislative expression manifests a legislative intent to subject to the inhibition of the statute every mine in the State and not to limit the prohibition to coal mines, as expressed in the title of the act of 1897, and as these statutes were intended to protect women and children of tender age from incurring the hazard and danger incident to the operation of mines by imperatively preventing their employment, it should be liberally construed so as to effectuate the humane intention of the legislature and the courts should not get in its way or whittle it down; and the word "any" used in the section of the Code must be given its usual and ordinary signification, and be held to mean all or every mine, and, thus construed, the prohibition applies to all mines of whatever kind or character in the State, and the later section raises the age of boys from 12 to 14 years, and therefore the employment by a mine operator of a boy under 14 years of age to work in a mine is a positive violation of this Code section and renders the employer liable for injury or death of such a boy.

Cole *v.* Sloss-Sheffield Steel & Iron Co. (Alabama), 65 Southern, 177, p. 178, May, 1914.

RETROACTIVE EFFECT.

Section 8536 of the revised codes of Montana did not create any right of action or destroy any defense available at the time of its enactment.

Maronen *v.* Anaconda Copper Co. (Montana), 136 Pacific, 968, p. 969, November, 1913.

APPLICATION TO ENTRIES.

Section 6871 of the revised statutes of Ohio imposes upon every miner under penalty the duty of securely propping the roof of the working places under his control, but this statute does not apply to entries as distinguished from the miners' working place, and notwithstanding the statute it is the duty of the mine owner or operator to furnish reasonably safe entries for ingress and egress and miners may presume that this duty has been performed.

Dasher *v.* Hocking Min. Co., 212 Fed., 628, p. 629, April, 1914.

APPLICATION TO CLASSES OF MINERS.

Sections 3983 and 3984 of the revised laws of 1910 of Oklahoma prescribe certain duties of mine operators toward employees, including among others the duty of daily inspection, and the requirements of these sections apply to the operators of lead and zinc as well as to those of coal mines, as it can not be assumed that the intent of the legislature was to provide with such minute care for the protection of workers in coal mines and to leave similar workers in lead and zinc mines without any protection whatever.

Big Jack Min. Co. *v.* Parkinson (Oklahoma), 137 Pacific, 678, p. 680, December, 1913.

MINE OWNER NOT AN INSURER AGAINST MINE EXPLOSION.

Section 1016 of the Alabama Code of 1907 requires the operator of every coal mine to maintain ample means of ventilation to an extent that will dilute, carry off, and render harmless the noxious gases generated in the mine, and the section applies only to noxious gases generated in the mine and is intended to require the operator to fan it out, or to so ventilate the mine as to prevent all harmful results from such noxious gas; but the statute does not make the mine owner an insurer under any and all conditions against mine explosions or make him liable for certain unavoidable accidents, but it is confined to injuries resulting from harmful and noxious gases generated in the mine, but does not make him an insurer against gas not generated in the mine, which is released or enters therein from its natural state by moving the layers of coal which held it in the gas pockets; and in this respect the act of 1907 differs from the act of 1911 as the latter act evidently makes a distinction between noxious and explosive gases and includes both.

Walker *v.* Birmingham Coal & Iron Co. (Alabama), 63 Southern, 1012, p. 1013, December, 1913.

STATUS OF MINE CHANGED.

The statute of Pennsylvania (Laws, p. 78) applies to mines employing more than 10 men in any one period of 24 hours, and in an action by a miner for injuries caused by an alleged violation of a statutory regulation, where the evidence shows that at the time of the construction of an entry at some time previous to the accident, some 12 to 13 men in each 24 hours were employed in the mine, is sufficient to show that the mine was within the statutory class at the time of the accident, for the reason that after the mine is once brought within the act it is presumed to remain there until something affirmatively appears to the contrary.

Smith *v.* Stoner (Pennsylvania), 89 Atlantic, 795, p. 796, January, 1914.

ACTION FOR WRONGFUL DEATH.

The statute of Illinois (Laws 1899, p. 300) applies to employer and employee in mining coal and gives another remedy for damages applicable only to persons engaged in mining coal, in which the liability of the employer rests upon different grounds from that of employers in other lines of employment, and if in such case the death of a miner is occasioned by any willful violation of the requirements of the act, the miner is exempted from the obligations to exercise care for his own safety, and the statutory action may be maintained although there was a want of such care.

McFadden *v.* St. Paul Coal Co. (Illinois), 105 Northeastern, 314, p. 315, June, 1914.

ADOPTION OF ACT BY EMPLOYER AND NOT BY EMPLOYEE.

In an action by a miner against a mine operator to recover damages for injuries alleged to have been sustained by him while working in a coal mine on the alleged ground of negligence for failure to furnish a safe working place, if the employer and the employee both accepted the provisions of the workmen's compensation act of Illinois (Laws, 1911, p. 314), the relation is one of contract, of which contract the law is a part; but if either elects not to come under the law and so notifies the proper authorities, then there is no such contract; and in such case if the mine operator has exercised the right of election and refused the benefits of the act, then the miner seeking redress for the injuries sustained is not bound by such contractual relation, and he is not limited in his recovery to the compensation provided by the act, but in such case the parties are remitted to their action at law and are governed in all respects by the rules and principles of law applicable to such actions except as to the matter of the defenses of assumed risks, fellow-servants and contributory negligence.

Crooks *v.* Tazewell Coal Co. (Illinois), 105 Northeastern, 132, p. 134, April, 1914.

CONSTITUTIONALITY OF OHIO COAL WEIGHING ACT.

The Ohio act of February 5,1914 (104 Ohio Laws, 181), entitled "An act to regulate the weighing of coal at the mines," does not restrict the right of contracting for the labor of miners by the day or week or month or year, or in any other manner, except as to quantity that the operator may deem proper; and if the miner or loader is to be paid by the ton or other weight, the right of contract is then curtailed to the extent that he shall be paid according to the total weight of the coal contained in the mine car, such contents to include however, no greater percentage of slate, sulphur, rock, dirt, or other impurities than is unavoidable, as determined by the Industrial Commission; and the act permits the employer and miner to stipulate as between themselves what percentage of coal commonly known as nut, pea, dust, and slate shall be allowed in the output of the mine, and the act can not be said to be unconstitutional, and it is not repugnant to any constitutional provision, State or Federal.

Rail & River Coal Co. *v.* Yable, 214 Fed., 273, p. 281, May, 1914.

A Federal court can not say that the act of February 5, 1914, of Ohio (104 Ohio Laws, 181), entitled "An act to regulate the weighing of coal at mines," does not provide for the health, safety, and general welfare of employees, in that it supplies an incentive for more effectually securing the removal of fine coal and coal dust to the surface and thereby minimizing or dissipating the danger arising from their continued presence in the mine; nor can the court say that the legislature acting within the scope of section 36 of the act may not say that the business of mining coal is so far affected with a public interest as to justify appropriate regulation of the manner of paying employees when they are to be paid according to the quantity produced, and when such regulatory statute will operate to allay discord and strive to conserve the coal supply.

Rail & River Coal Co. *v.* Yable, 214 Fed., 273, p. 281, May, 1914.

STATUTORY RIGHTS AND DUTIES.

Statutory Rights Granted.
Duties Imposed on Operator.
Duties Imposed on Miner.

STATUTORY RIGHTS GRANTED.

MINER ENTITLED TO PROTECTION OF STATUTE.

In an action for damages for the death of a miner caused by the alleged violation of a statutory provision it is necessary that the proof show that at the time of the injury resulting in the death of a miner he belonged to the class of persons for whose protection and benefit the statute was enacted; but under the statute of Illinois requiring a mine operator to station at the bottom of the shaft of his mine a competent man charged with the duty of attending to signals and enforcing the rules governing the carriage of men on cages and which required such shaft man to be at his post of duty half an hour before the hoisting of coal begins in the morning and to remain for half an hour after the hoisting ceases for the day, the deceased miner was entitled to the protection of the statute and to the presence of the shaft man if he reached the bottom of the shaft within the time the shaft man is required to be on duty, although he entered the shaft before he was required to do so, and if injured within that time he was a member of that class of persons for whose health and safety the mining act was passed and the fact that he descended the shaft before he was required to do so did not render him a trespasser or deprive him of the protection of the statute.

Brunnworth *v.* Kerens-Donnewald Coal Co. (Illinois), 103 Northeastern, 178, p. 184, December, 1913.

DUTIES IMPOSED ON OPERATOR.

DELEGATION OF DUTY—INDEPENDENT CONTRACTOR.

The owner and operator of a mine can not relieve himself of the duties imposed by the statute of Kentucky for the protection of human life by entering into a contract with a miner to mine coal at a specified price per ton.

Interstate Coal Co. *v.* Trivett (Kentucky), 160 Southwestern, 728, p. 731, November, 1913.
Interstate Coal Co. *v.* Trivett (Kentucky), 160 Southwestern, 731, p. 732, November, 1913.
Employers' Indemnity Co. *v.* Kelly Coal Co. (Kentucky), 160 Southwestern, 914, p. 1916, November, 1913.

SAFETY OF CAGES.

Section 8356 of the revised codes of Montana requires the operator of a shaft mine to keep the doors on the safety cage closed when carrying men, but the statute does not impose on the operator the duty of employing a person whose sole duty it would be to open and close the cage door, nor does it prohibit the operator from imposing such duty upon a person having other duties to perform that in no way interfere with the duty of opening and closing the cage door. While the act is penal in its character, yet it is a police regulation designed to protect the lives of miners and was not intended to lay an embargo upon the mining industry, and this section does not contemplate that it would be necessary that two or three men be employed to wait upon one man who is actively engaged in mining; but it does impose the duty and contemplates that in its discharge some one shall be employed to act for the operator in performing the manual labor of opening and closing the cage doors, and if the person designated to do this is capable, understands the method to be pursued in the employment, and is not incumbered with other duties which interfere with the discharge of opening and closing the door, then the mine operator has discharged its duty.

Maronen *v.* Anaconda Copper Co. (Montana), 136 Pacific, 968, p. 972, November, 1913.

DUTY TO FURNISH SAFE CAGE.

The statute of Missouri (R. S. 1909, sec. 8456) makes it the duty of a mine operator to provide safe means of hoisting and lowering persons in a cage, so as to keep safe so far as possible persons descending into and ascending out of the shaft of a mine, and this provision may be regarded as a statutory expression of an elementary common-law rule; and a mine operator who has provided a hoisting cage for transportation of its miners is under the duty to exercise reasonable care to maintain a cage in a reasonably safe condition for use; and while a mine operator is not an insurer of the safety of a miner and the mere fact that a miner was injured while in the discharge of his duties of employment by a defect in the cage would not of itself raise an inference of negligence, but the question is whether or not the operator exercised proper care to discover the presence of defects in the cage that would enhance the natural risks of the service; and knowledge, actual or constructive, of a defect in appliances must be brought home to the employer before a liability exists; but the evidence of the injured miner to the effect that he was dumped through the floor of the cage and injured in the fall, together with the evidence of the cager that large lumps of coal had been falling from the ascending cage for a long period is sufficient to raise an inference of negligence and that the injury was in fact caused by the failure of the mine operator to make proper inspection of the cage.

Ronchetto *v.* Northern Central Coal Co. (Missouri Appeals), 166 Southwestern, 876, p. 879, May, 1914.

NO EXCUSE FOR NONCOMPLIANCE.

The duty of equipping a safety cage with steel doors and keeping them closed when carrying miners, as provided by section 8536 of the revised codes of Montana, is an absolute one, in the sense that the employer will not be heard to say that by the exercise of ordinary care he can not comply with the requirement.

Maronen *v.* Anaconda Copper Co. (Montana), 136 Pacific, 968, p. 969, November, 1913.

DUTY TO FURNISH PROPS—APPLICATION OF STATUTORY RULE.

Section 2739*b*–7 of the Kentucky statutes requires the owner or operator of a mine to furnish to the miners a sufficient number of caps and props, the latter to be properly prepared for use by the miner in securing the roof in his room in the mine, and this rule does not apply only where it is necessary to use them to support the permanent roof of the mine but applies equally to a case of mere draw slate, though not usually practicable or customary to prop; but as the chief purpose of the statute is the protection of the miner, and it may happen that draw slate may be propped while the miner is engaged in cutting down the coal, and under such circumstances, where a miner's request for props is not complied with and the miner is injured, the question whether or not the failure to furnish the props was the proximate cause of his injury, and where it appears that it was neither customary nor practicable to prop the draw slate, the question of the proximate cause of the miner's injury become a question of fact for the jury.

Interstate Coal Co. *v.* Trivett (Kentucky), 160 Southwestern, 728, p. 730, November, 1913.

METHOD OF OPERATING MINE.

The statute of Wisconsin (Laws 1911, chap. 485) provides that no employer shall fail to use methods reasonably adequate to render the place of employment safe, and a mine operator can not escape liability for an injury to a miner caused by the fall of rock, on the ground that he adopted the usual and customary methods of doing the work, as this does not answer the requirement of the statute.

Dolphin *v.* Peacock Min. Co. (Wisconsin), 144 Northwestern, 1112, p. 1115, January, 1913.

CARE REQUIRED IN INSPECTION.

Under the liability act of Alabama (Code, sec. 3910) the measure of care and diligence for the performance of the duty of inspection for defects in the ways, works, machinery, or plant of a mine operator is the exercise and employment of the care, prudence, and diligence a reasonably prudent man would exercise and employ under similar circumstances to ascertain whether there are defects in the condition of the ways, works, machinery, or plant, bearing in mind that the operator is not accountable as an insurer of the premises, and that the character and frequency of the inspection must depend upon the subject of the duty, whether it is machinery peculiarly subject to wear and a self-created deficiency in its vital parts or some other agency of the operator's business in which normal use does not ordinarily create defects in its condition.

Espey *v.* Cahaba Coal Co. (Alabama), 64 Southern, 753, p. 755, February, 1914.

INSPECTION—FAILURE TO PERFORM—LIABILITY.

Section 7381 of the Remington and Ballinger Code of the State of Washington provides that in all mines generating fire damp the owner or operator shall cause every working place to be examined every morning with a safety lamp, by a competent person, and a record of such examination entered in a book kept for that purpose, and that such book must always be produced for examination at the request of the inspector, is less drastic, and is evidently intended to take the place of section 9 of the act of 1891, requiring all such mines "to be kept free from gas of every kind."

Pacific Coast Coal Co. *v.* Brown, 211 Fed., 869, p. 872, February, 1914.

DUTY TO PROVIDE SAFE WORKING PLACE.

The fact that all the miners in a mine were working under the direction of the mine manager in clearing out a mine for operation after having been shut down for several months, and all were under general directions to make dangerous places safe, yet this does not relieve the owner or operator from the duty of having the mine examined, the mine examiner from the duty of marking dangerous places, or the mine operator or owner from the duty of having danger signals properly placed, as required by the statute of Illinois; and if such general instructions to make all dangerous places safe were sufficient to cause the miners to assume the hazards of the employment, then there would be no necessity for or any use of examination, as the miners could ascertain the dangerous places in their own way and make them safe at their own risk; but the conditions under which a miner may work at a dangerous place at his own risk are those where the owner has complied with the statute by having the mine examined, the dangerous places marked by the mine examiner, and the miner is sent to that particular place by the direction of the mine manager to make safe the particular dangerous conditions there existing.

Piazzi *v.* Kerens-Donnewald Coal Co. (Illinois), 104 Northeastern, 200, p. 202, February, 1914.

SAFE APPLIANCES—USE OF INDICATOR.

The statute of Idaho requires a hoist used in handling men in mines to be equipped with an indicator placed in clear view of the hoist engineer and so adjusted as to show at all times the exact location of the bucket, cage, or skip, and in an action by a miner for injuries received while riding on a skip and by reason of its coming in contact with the bulkhead it is proper to show that the hoist was not equipped with the indicator as required by the statute, and to show that the method used for signaling to the man at the hoist was defective and that because of such defect the injury occurred.

Federal Min. & Smelting Co. *v.* Hodge, 213 Fed., 605, p. 608, May, 1914.

DUTY TO VENTILATE MINE.

An operator of a coal mine is liable, for failure to properly ventilate his mine as required by the Kentucky statute, to a miner who was overcome by the presence of black damp, where it appears that the injury consisted of being overcome by the black damp, and if breathed for any length of time small quantities of the gas cause headache and nausea followed by pains and weakness in the back and limbs, while larger quantities produce death, and a recovery may be had under such circumstances, though there was no direct evidence tending to show an actual violation of the statute.

Mt. Morgan Coal Co. *v.* Shumate (Kentucky), 163 Southwestern, 1099, March, 1914.

DUTIES IMPOSED ON MINER.

KEEPING WORKING PLACE SAFE.

Section 6871 of the Revised Statutes of Ohio requires every miner under penalty to securely prop the roof of any working place under his control to a distance of 15 feet back from the face of his working, and the statute applies primarily to a miner actually engaged in mining coal and constantly changing his working place, and it has no application to a miner originally engaged as a general repair man and electrical wire hanger, but was temporarily employed by the foreman and requested and directed to assist a timberman in taking out bottom coal in an entry and proceeded to perform the work according to the directions of the foreman, and while so engaged was injured by a fall of slate from the roof of such entry.

Dasher *v.* Hocking Min. Co., 212 Fed., 628, p. 630, April, 1914.

DUTIES OF MINER TO MAKE WORKING PLACE SAFE.

The statute of Montana (Coal Mining Code, 1911, sec. 83) imposes on the miner the duty of inspecting and keeping safe his working place, and where a miner was employed running an entry or tunnel some 12 feet wide through a blanket vein of coal varying in height according to the thickness of the vein, and at certain intervals the work was measured up and paid for by the company, the miner's working place under such circumstances, and which under the statute he is required to keep safe, is his working place while loading at the point where the coal was actually put into the cars, and while drilling and blasting his working place is at the face of the entry; but the portion of the entry so completed and measured up and paid for by the operator is not a working place within the meaning of this statute, though the miner was required to make use of that portion of the tunnel to get empty cars, powder, and other appliances; and it was the duty of the mine operator to inspect and keep safe all that part of the tunnel so completed and paid for, and for any negligence in this respect the operator is liable for an injury to a miner occurring in that part of the tunnel so completed and accepted by the operator.

McInnees *v.* Republic Coal Co. (Montana), 140 Pacific, 235, p. 236, April, 1914.

MINER IN CHARGE—PROPPING ROOF.

The statute of Ohio requires every miner under a penalty to securely prop the roof of his working place, and no recovery can be had by a miner for an injury resulting from his failure to prop the roof as required; and if two miners are equally in control of the working place, the fact that one is distinguished as timberman does not relieve the other of liability.

Dasher *v.* Hocking Min. Co., 212 Fed., 628, p. 629, April, 1914.

MINER IN CONTROL OF ROOM—MEANING.

Under section 6871 of the Revised Statutes of Ohio, imposing upon a miner under penalty the duty of securely propping the roof of any working place "under his control," the question of actual control is primarily one of fact, and the statute is not held to mean that every person employed in a mine for any purpose is in control of the room in which he is employed; but the statute is more properly limited to those persons actually engaged as miners in taking out coal and thereby removing the natural props of the roof, and does not apply to persons specially employed to perform duties having no connection with the weakening or removal of these natural supports.

Dasher v. Hocking Min. Co., 212 Fed., 628, p. 634, April, 1914.

OPERATOR'S FAILURE TO COMPLY WITH STATUTORY REGULATIONS.

Failure to Comply Generally.
Negligent Failure to Comply.
Willful Failure to Comply.

FAILURE TO COMPLY GENERALLY.

PLEADING NEGLIGENCE AND LIABILITY.

In an action by a miner for damages for injuries caused by the alleged violation of a statute on the part of the operator, the complaint will be sufficient if it advises the defendant of the negligence charged so as to inform him of what he is expected to meet at the trial, and the injured miner is not required to plead in detail such facts as are peculiarly within the knowledge of the operator; and a complaint is sufficient if it alleges that in the vicinity where the plaintiff was directed by the mine boss to work there was loose rock and slate which it was necessary for him to go under while performing the particular work required of him, and that the defendant had full knowledge of all such defects before sending the plaintiff there to work, and the defective condition of the roof of the mine could have been easily ascertained by an inspection, together with an averment that the plaintiff did not know of the loose and dangerous condition of the rock and slate, and that the mine operator gave him no warning of its dangerous condition.

Domestic Block Coal Co. v. Holden (Indiana Appeals), 103 Northeastern, 73, p. 75, November, 1913.

PROXIMATE CAUSE OF INJURY—QUESTION OF FACT.

The statute of Illinois (Mines and Miners Act, 1899, sec. 28) requires operators of coal mines to keep at the top and bottom of the shaft a competent man charged with the duty of attending to the signals and to enforce the rules governing the carriage of men on cages, and also requires at the landing a light sufficient to show the landing and surrounding objects distinctly, and a light at the bottom of the shaft so that miners may clearly discern the cage and objects in the vicinity; and in case of a violation of this statute in failing to maintain a light at the bottom of the shaft and a miner was killed in attempting to board a cage after it had started, the question of whether or not the absence of the light required by the statute was the proximate cause of the death of the miner is a question of fact to be determined by a jury under all the circumstances of the case.

Brunnworth v. Kerens-Donnewald Coal Co. (Illinois), 103 Northeastern, 178, p. 180, December, 1913.

FAILURE TO COMPLY—LIABILITY—DEFENSES EXCLUDED.

In an action by a miner against a mine operator for damages for injuries received while working in a mine, proof is admissable to show that the operator had rejected the provisions of the workmen's compensation act of Illinois, and hence can not set up the defenses of assumed risks, fellow-servants, or contributory negligence, except that contributory negligence may be shown for the purpose of lessening the damages; and the operator can not prove by expert witnesses that the mine was completely and properly equipped, constructed, and operated, where other employees of the operator had testified in its behalf as to the actual condition of the entry where the accident occurred, at the time of the accident.

Crooks v. Tazewell Coal Co. (Illinois), 105 Northeastern, 132, p. 134, April, 1914.

FAILURE TO VENTILATE MINE.

Section 1016 of the Alabama Code of 1907 requires the operator of every coal mine to provide and maintain ample means of ventilation for the circulation of air through the mine entries and to working places to an extent that will dilute, carry off, and render harmless the noxious gases generated in the mine, and requires mine operators to keep their mines ventilated to the extent of rendering them harmless from noxious gases; and the legislature meant more than mere requiring the nondelegable duty of furnishing the means for ventilation, but made it the imperative duty of the operator to so ventilate the mine as to render it harmless from noxious gases generated therein.

Walker v. Birmingham Coal & Iron Co. (Alabama), 63 Southern, 1012, p. 1013, December, 1913

FAILURE TO INSPECT.

A miner injured by rock falling from the roof of an entry is entitled to recover from the mine operator for failure to discharge statutory duty in making inspection and propping the roof, where the miner called the attention of the mining boss to the defective condition of the roof and asked to be permitted to make the roof safe, but permission was refused, the mine boss telling him that he would have a company man fix the roof before the following morning, and where on returning in the morning the miner found rock on the traveling way of the entry and, supposing that the company man had taken the rock down in accordance with the promise, proceeded to clear away the rock on the floor and while so doing was injured from a fall of rock in the roof, which had not been repaired or made safe according to the promise.

Macketta *v.* Missouri, Kansas, etc., R. Co. (Kansas), 140 Pacific, 877, May, 1914.

FAILURE TO INSPECT MACHINERY.

The liability act of Alabama (Code, sec. 3910), in the particular that it predicates negligence of the failure of the mine operator to discover defects in the condition of the ways, works, machinery, or plant, contemplates inspection to the end indicated and the duty to inspect exists just as the duty to remedy defects in conditions exists but the act has not extinguished the duty of inspection, but such duty may be delegated to a competent miner in whose selection the operator has employed the requisite care.

Espey *v.* Cahaba Coal Co. (Alabama), 64 Southern, 753, p. 755, February, 1914.

INJURY FROM DEFECTIVE APPLIANCES—LIABILITY.

Under the statute of Alabama (Code, sec. 3910) if the defect counted on is found to have existed and to have caused the death of the miner as alleged, still the operator can not be held liable unless the defect complained of arose from or had not been discovered or remedied owing to the negligence of the operator, or of some person in his service and entrusted by him with the duty of seeing that the ways, works, machinery, or plant were in proper condition, as it is essential to a recovery under the first subdivision under the liability act that the proof must show negligence within the condition of the act.

Espey *v.* Cahaba Coal Co. (Alabama), 64 Southern, 753, p. 755, February, 1914.

REFUSAL TO PERMIT SURVEY.

The Revised Statutes of Indiana (secs. 8599–8600, Burns, 1908) provide that the owner or tenant of any land on which a coal mine is opened and operated, and the person or persons owning or operating such mine, shall permit any person interested in or having title to any land coterminous with the land on which such mine is located to have ingress and egress with surveyors and assistants into such mine for the purpose of measuring and surveying the mine in order to ascertain whether or not any coal has been mined and taken from his land, and any owner or occupant who shall refuse such permission shall forfeit the sum of $100, and the statute being penal must be strictly construed; and to enable a person to recover the stated penalty he must show a substantial violation of the statute and must show not only that he owns the land coterminous with the land on which the mine is situated but that the coal mine sought to be surveyed was open and being operated, and that some request had been made by him of the owner or operator for a permit to enter the mine for the purpose of making such survey and measurements, and that such permission had been refused.

Rowell *v.* Snoddy (Indiana Appeals), 104 Northeastern, 90, February, 1914.

NEGLIGENT FAILURE TO COMPLY.

FAILURE TO SUPPLY PROPS.

The statute of Kansas requires a mine operator to supply prop timber of suitable length and size and easy of access, and a mine operator can not avoid liability for injury to a miner because of its failure to supply such prop timber by delegating the duty to some agency, such as the car drivers; and the statute neither requires nor contemplates that the miner shall request or demand of the operator that the prop timber be supplied before the obligation of the statute arises; and proof that a car driver failed to communicate the request to the mine boss will not relieve the operator from liability.

Le Roy *v.* Missouri, Kansas, etc., R. Co. (Kansas), 138 Pacific, 646, February, 1914. Ricci *v.* Cherokee & Pittsburg Coal & Min. Co. (Kansas), 140 Pacific, 844, p. 866, May, 1914.

DUTY OF OPERATOR.

The statute of Kentucky (sec. 2739*b*-7) imposes upon the operator of a coal mine the peremptory and nondelegable duty of furnishing to the miner such props and caps as are necessary to make safe the roof of the miner's working place when request therefor is made; and a miner who is injured by a failure of the mine operator to perform this duty may recover damages for the injuries sustained unless the danger of working in the place where he was injured was so imminent and obvious that an ordinarily prudent person would not have worked therein.

Continental Coal Corporation *v.* York (Kentucky), 167 Southwestern, 131, p. 132, June, 1914.

WILLFUL FAILURE TO COMPLY.

WILLFUL OR NEGLIGENT VIOLATION.

In an action by a miner for injuries caused by the failure of the mine operator to supply the miner with suitable prop timber the miner is not required to prove willfulness on the part of the operator in failing to comply with the provisions of the statute, as the statute gives a cause of action for injury occasioned by any violation of the act, and where the operator established its own method and means for complying with the statutory obligation and makes the car driver its agent to receive and forward requests for props and to deliver the props to the miners, and having chosen such method its responsibility for a failure resulting from any deficiency in the means by which its statutory obligation was to be complied with, it will not be permitted to avoid liability for failure to comply with the statute because the agency employed by it had proved untrustworthy; and a willful failure to comply with such a statute does not involve bad purposes or determined obstinacy in order to create liability, but if the operator intentionally suffers mining operations to proceed without taking the prescribed precautionary measures he is guilty of a willful failure within the meaning of the law.

Le Roy *v.* Missouri, Kansas, etc., R. Co. (Kansas), 138 Pacific, 646, February, 1914.
Ricci *v.* Cherokee & Pittsburg Coal & Min. Co., (Kansas), 140 Pacific, 844, p. 866, May, 1914.

VIOLATIONS OF STATUTORY REGULATIONS.

VIOLATIONS BY OPERATOR.
VIOLATIONS BY MINER.

VIOLATIONS BY OPERATOR.

CAUSAL CONNECTION WITH INJURY.

Section 8546 of the revised code of Montana prohibits the storing of more than 3,000 pounds of explosives in a mine, and a violation of this section is negligence per se, but such negligence can not become the basis of recovery without proof of a causal connection between it and the injury complained of; but when a quantity of dynamite by exploding produces injury the causal connection is established, and if the storing of the quantity is negligence then a causal connection is made by the explosion between the negligence alleged in storing the excessive amount and the injury complained of. However, a plaintiff in such case is not required to show a specific causal connection between the injury and the existence or explosion of that portion of the dynamite exceeding 3,000 pounds, as this would defeat the purpose of the statute, considered as the foundation of civil liability; nor is the per se negligence answered by saying that a quantity of dynamite less than 3,000 pounds might have exploded under the same circumstances or that the explosion of a quantity less than 3,000 pounds under the same circumstances might have produced the injury.

Westlake *v.* Keating Gold Min. Co. (Montana), 136 Pacific, 38, p. 40, October, 1913.

The storing of explosives in a mine in excess of the amount permitted by section 8546 of the revised codes of Montana is negligence per se, but to justify the recovery by a miner injured by an explosion there must be a causal relation between the storing and the injuries complained of, and if the storing and the consequent explosion did not cut off the escape of the miner working in the mine, and if he was so located that his means of egress were not affected by the explosion, then such per se negligence is not available to him as a basis of recovery.

West Lake v. Keating Gold Min. Co. (Montana), 136 Pacific, 38, p. 41, October, 1913.

CRIMINAL AND CIVIL LIABILITY.

Section 8536 of the statute of Montana requires a mine operator to keep the doors on the safety cage in a shaft mine closed when carrying men into or out of the mine and prescribes a criminal liability for its violation; but the fact of such criminal liability does not render a mine operator immune from civil liability for an injury resulting from a violation of the section.

Maronen v. Anaconda Copper Co. (Montana), 136 Pacific, 968, p. 969, November, 1913.

FAILURE TO MAINTAIN A SAFE ENTRY.

The statute of Pennsylvania (Laws, p. 78) provides that all entries shall have a clear level width not less than 2½ feet between the side of the car and the rib to allow the driver to pass his trip safely at points where he is required to sprag his cars, and a mine operator is liable for an injury to a car driver where he fails to provide space sufficient to permit the car driver to keep clear of the cars and where such failure is the proximate cause of the injury.

Smith v. Stoner (Pennsylvania), 89 Atlantic, 795, p. 796, January, 1914.

FIRING SHOTS IN VIOLATION OF STATUTE—DEATH FROM DUST EXPLOSION.

A mine operator violating the provisions of section 8477 of the Revised Statutes of Missouri, 1909, in that shots used in blasting coal were fired before the miners had time to leave the mine, thereby producing a dust explosion, resulting in the death of a miner, can not escape liability either on the ground that it had been a practice to fire such shots before the miners were out, though known to be dangerous and to be in violation of law, or on the ground that the operator operated the mine under an arrangement with an independent contractor by which such independent contractor was to mine coal off the vein or solid as it lay in the earth and load the same at the point thus mined into the operator's cars, and that the operator would then transport it by means of his equipment and the regular operation of the entire mine, to the bottom of the shaft and thence to the surface, and that such independent contractor was paid by the car thus loaded by him at the point of blasting, as the right to recover does not depend upon the tracing of a direct relation from the deceased to the mine operator, but upon the duty owed him by both the contractor and the operator; and as the operating company never parted with its proprietorship and occupancy of the mine or with the control of its operation, he could not therefore relieve himself of the statutory duty by means of any principle applicable to the law relating to independent contractors.

Gray *v.* Grand River Coal & Coke Co. (Missouri), 162 Southwestern, 277, p. 278, January, 1914.

FAILURE TO EMPLOY FOREMAN.

The statute of West Virginia requiring a mine operator to employ a mine foreman and place him in charge of the underground workings of a mine does not absolve the operator from his common-law duty to exercise reasonable care to provide reasonably safe machinery, tools, and appliances for use in the mine and make the mine a reasonably safe place for work, except in so far as the duty is devolved upon the mine foreman, nor does it absolve the operator from liability from injury resulting to a miner in the mine from his failure to make such provision, or his provision of defective or unsafe appliances, or his failure of duty as to the safety of the mine as a place of work in all instances in which such duty is not cast upon the mine foreman.

Humphreys *v.* Raleigh Coal & Coke Co. (West Virginia), 80 Southeastern, 803, p. 805, February, 1914.

EMPLOYMENT OF BOY OF PROHIBITED AGE.

In an action for the death of a boy employed in a mine the complaint is sufficient where it alleges that the intestate was a boy under 14 years of age and while in the employment of the defendant at its ore mines in the State of Alabama, and while in the discharge of his duties in the course and line of his employment as such and after he was so employed, he was struck by one of defendant's tramcars and thereby so injured that he died from the effects thereof, and that such injuries and death were proximately caused by the employment of the deceased boy in said mine in violation of the statute of Alabama which prohibits the employment of boys under 14 years of age to work in or about mines in the State.

Cole *v.* Sloss-Sheffield Steel & Iron Co. (Alabama), 65 Southern, 177, May, 1914.

PLEADING CONTRIBUTORY NEGLIGENCE.

In an action for damages for the death of a boy under 14 years of age employed in a mine in violation of the statute of Alabama, an answer by the defendant to the effect that the boy was guilty of negligence which proximately contributed to his death, which negligence consisted in the fact that at the time the intestate suffered the injuries causing his death there was in force and effect a rule prohibiting employees performing the duties that such intestate was employed to perform from riding on cars operated on the track on which the car or tram that struck the intestate was being run when it struck him, and of which rule the intestate well knew, and that immediately before the intestate received the alleged injury causing his death he was riding on one of the cars in violation of such rule, is insufficient because it did not aver that the boy had sufficient capacity to appreciate the danger or risk to be incurred in not observing the rule.

Cole *v.* Sloss-Sheffield Steel & Iron Co. (Alabama), 65 Southern, 177, p. 179, May, 1914.

MINING COAL NEAR DIVISION LINE—SEPARATE PENALTIES RECOVERABLE.

The statute of West Virginia (sec. 3920, Code 1913) prohibiting the owner or tenant of any land containing coal from removing the coal within 5 feet of the division line without the consent of the other interested person, and giving to the injured person the right to sue and recover a penalty of $500, makes each encroachment a separate wrong and gives an injured party a right of action for as many different penalties, whether such encroachments are made at the same time or at different times.

Darby *v.* Davis Coal & Coke Co. (West Virginia), 81 Southeastern, 1124, p. 1125, May, 1914.

MINING NEAR DIVISION LINE—LIMITATION OF ACTION.

An action for the recovery of the statutory penalty of $500 which accrues in favor of the owner of land containing coal as against an adjoining owner who mines the coal within 5 feet of the division line, the cause of action being for the recovery of a penalty, is barred by the statute of limitations after one year.

Gawthrop *v.* Fairmont Coal Co. (West Virginia), 81 Southeastern, 560, April, 1914.

VIOLATIONS BY MINER.

VIOLATION OF DUTY—NO RECOVERY.

The statute of Montana requires a mine operator to keep the doors on the safety cage in a shaft mine closed while carrying miners, and if a mine operator employs a person whose sole duty it is to open and close the cage doors at particular stations and he neglects to perform such duties while he himself is being lowered or hoisted, and by reason of such failure to perform his duty and keep the door closed he is injured or killed, neither he in the one instance nor his heirs or personal representatives in the other can recover, as in such case he would be responsible for his own injury or death.

Maronen *v.* Anaconda Copper Co. (Montana), 136 Pacific, 968, p. 972, November, 1913.

KNOWLEDGE OF VIOLATION BY OTHERS—EFFECT ON RIGHTS.

In an action against a mine operator for the death of a miner caused by the breaking of the cable in hauling the miners out of the mine, the action can not be defeated by showing that the deceased miner violated the statute of Pennsylvania which prohibits more than 10 persons from riding out of the mine on a truck or in a cage at one time, where it appeared that he was the first person on the truck and there was nothing to show that he knew how many persons were on the truck before it started and whether the number was in excess of the number permitted by the statute and where there was nothing to show that if he had known of the excessive number opportunity was given him to alight in safety; and more especially the action can not be defeated on this ground where the evidence showed that the breaking of the cable was not caused by the overloading of the car.

Dodd *v.* Summit Branch Min. Co. (Pennsylvania), 88 Atlantic, 927, p. 929, June, 1913.

MINER'S VIOLATION—PLEADING.

In an action by a miner for an injury caused while riding on the bail of a skip in violation of the statute of Idaho which forbids any miner to ride on a bail of the skip, the defense of the violation of the statute must be interposed in a trial court and can not be suggested as a defense of the action for the first time on appeal.

Federal Min. & Smelting Co. *v.* Hodge, 213 Fed., 605, p. 608, May, 1914.

CONTRIBUTORY NEGLIGENCE OF MINER.

RELIANCE ON PERFORMANCE OF DUTY.

A miner working in a mine has the right to rely upon the performance of a statutory duty on the part of the mine examiner, and where the mine examiner is required by statute to mark dangerous places in the roof the absence of a mark indicates that in the opinion of the mine examiner the place is not dangerous, and under such circumstances a miner can not be held guilty of contributory negligence in working under a clod in the roof, if not so marked, though it may have a dangerous appearnce.

Piazzi *v.* Kerens-Donnewald Coal Co. (Illinois), 104 Northeastern, 200, p. 202, February, 1914.

EXERCISE OF DUE CARE—PROOF EXCUSED.

In an action for the death of a miner against a coal mine operator under the statute of Colorado making an employer liable for injuries or death of an employee resulting from the negligence of another employee where the deceased employee was in the exercise of due care at the time of his death, the plaintiff is not required to prove affirmatively that the deceased was at the time of his death in the exercise of due care, but the burden of proving contributory negligence is upon the employer, as it was not within the purpose of the fellow-servant act to change the rule as to the burden of proving contributory negligence, but the requirement as to the injured or deceased employee "being in the exercise of due care" was obviously inserted from motives of caution, that it might not be supposed that the declared liability of an employer was intended to be absolute and without regard to any negligence of the injured or deceased employee.

National Fuel Co. *v.* Maccia (Colorado), 139 Pacific, 22, p. 24, March, 1914.

DEFENSE OF CONTRIBUTORY NEGLIGENCE ABROGATED.

The general statutes of Kansas (sec. 4987) require a mine operator to inspect the roof of the mine where its employees are working, and in an action by an injured miner against a mine operator for failure to inspect the roof of a mine as required by the statute, the statute itself in effect abrogates the defense of contributory negligence on the part of the miner.

Baisdrenghien *v.* Missouri, etc., R. Co. (Kansas), 139 Pacific, 428, March, 1914.

The statute of Nevada (Revised Laws, sec. 5651) provides that a miner's contributory negligence shall not bar recovery, and the effect of the statute is to supersede the common-law rule of contributory negligence and to substitute the rule of relative or comparative negligence, and slight contributory negligence on the part of an injured miner will not prevent a recovery for an injury where the negligence of the operator was gross in comparison to that of the miner.

Peterson *v.* Pittsburg Silver Peak Gold Min. Co. (Nevada), 140 Pacific, 519, p. 592, April, 1914.

In an action for damages for the death of a miner caused by the alleged violation of the statute of Illinois, which requires a mine operator to keep a man stationed at the bottom of the shaft to enforce the rules governing the carriage of men on cages and to keep the shaft lighted, where it appeared that the miner lost his life while attempting to board the cage after it started, at the bottom of the shaft, and where at the time no shaft man was present and no light was maintained as required by the statute, the alleged contributory negligence of the deceased miner in attempting to board the cage can not be interposed as a defense.

Brunnworth *v.* Kerens-Donnewald Coal Co. (Illinois), 103 Northeastern, 178, p. 181, December, 1913.

QUESTION OF FACT.

In an action by a miner for injuries caused by the alleged failure of the mine operator to furnish props as required by the statute of Kansas, the contributory negligence of the miner in working in his room in the absence of such props is not available to the mine operator as a defense, and if it were so available it is a question of fact to be determined by the jury trying the case.

Le Roy *v.* Missouri, Kansas, etc., R. Co. (Kansas), 138 Pacific, 646, February, 1914.
Macketta *v.* Missouri, Kansas, etc., R. Co. (Kansas), 140 Pacific, 877, May, 1914.

DUTY TO FURNISH PROPS—CONTRIBUTORY NEGLIGENCE OF MINER.

Where a mine operator furnished the necessary props as required by the Kentucky statute (sec. 2739b), a miner injured by a fall of slate from the roof is guilty of contributory negligence where, with knowledge of the dangerous condition of the roof, he continues working in the dangerous place without setting the props, and the fact that it was more convenient to mine and handle the coal without the props will not excuse his negligence.

Branson *v.* Clover Fork Coal Co. (Kentucky), 164 Southwestern, 304, p. 305, March, 1914.

ASSUMPTION OF RISK—EFFECT.

RISKS ASSUMED BY MINER.

MAKING DANGEROUS PLACE SAFE.

By the mining act of Illinois it is the duty of timbermen in a mine to work in unsafe places and make them safe whenever and wherever directed by the mine manager, and a mine manager is only doing his statutory duty when he sends a timberman to clean up a fall and make a place safe, and in such case the operator can not be charged with a violation of a statutory duty in case of injury to the timberman causing his death; and while it is the duty of a mine operator to warn an inexperienced miner of unknown dangers, the rule does not apply where the danger was involved in the very nature of the employment and the nature of the work notified the timberman of the danger, and accordingly he was not exposed to any unusual, unnecessary, or unknown danger.

Kalinski *v.* Williamson County Coal Co. (Illinois), 104 Northeastern, 1097, p. 1099, April, 1914.

KNOWLEDGE OF DANGER.

An educated miner of 21 years' experience, who had served 8 years as a pit boss and had worked in a particular mine for 5 months, and who had admitted that he was more able to cope with mine dangers than the average man, and that he knew the dangers of the situation, and that within half an hour before he received an injury from falling rock that some of the rock falling from the roof of his room knocked some of the props out, and that such props were so short that he would not hear the rock crack at the top should the roof start to fall, and who admitted that he had the necessary tools at hand to utilize the posts in the room immediately available to him, and yet he failed to undertake to protect himself by properly setting any of the props, but preferred to wait for longer timbers to be sent to him, and who with his knowledge and the warning from the falling rock continued in his place of danger, assumes the risk and can not recover for an injury though the mine foreman and the mine operator may have been negligent in failing to furnish suitable props.

Peters *v.* Vesta Coal Co. (Pennsylvania), 90 Atlantic, 65, p. 66, January, 1914.

FAILURE TO PROP ROOF.

Section 6871 of the Revised Statutes of Ohio imposes upon every miner the duty of securely propping the roof of his working place and renders him liable to criminal prosecution for failing to do so, and under the statute this duty can not be shifted to another, and the failure to properly perform the duty will defeat a recovery by the miner in case of any injury caused by such failure.

Dasher *v.* Hocking Min. Co., 212 Fed., 628, p. 629, April, 1914.

MINER'S ASSUMPTION OF RISK NOT A DEFENSE.

Under the Pennsylvania act of May 15, 1893 (Pa. Laws, 78); requiring a mine operator to provide space sufficient in an entry to permit the driver of a car to keep clear of the cars, the defense that the miner—the car driver—assumed the risks incident to the employment and the risks incident in operating his cars in a tunnel narrower than that prescribed by the statute can not be interposed, but the operator who operates his mine in violation of the statute does in law assume the risks therefrom.

Smith *v.* Stoner (Pennsylvania), 89 Atlantic, 795, p. 796, January, 1914.

In an action for injuries by an employee caused by the alleged violation of a statutory duty on the part of the employer, the injured employee is not necessarily precluded from recovery because in doing the work he voluntarily adopted a way which was known to be dangerous, when a safer way was known and open to him, as in such cases the doctrine of assumption of risk has no application.

Sare *v.* Hoadley Stone Co. (Indiana Appeals), 105 Northeastern, 582, p. 585, June, 1914.

RISKS NOT ASSUMED BY MINER.

RELIANCE ON OPERATOR'S PERFORMANCE OF DUTY.

While a miner performing the work assigned him in a mine is bound to exercise due care for his own safety, yet he may assume, in the absence of notice to the contrary, that the mine operator and overseer or foreman have performed their duty in respect to the care of the entry where he is working and that the operator has employed a competent and practical inside overseer or mining boss, as required by the statute, whose duty it is to keep a careful watch over all traveling ways and see that as the miners advance their excavations all loose coal, slate, and rock overhead are carefully secured against falling in or upon the traveling ways, and a miner so engaged may rely upon the presumption that the mining boss has performed his duty, and the statute to this extent entirely shifts the risks of the employment from the miner to the operator.

Baisdrenghien *v.* Missouri, etc., R. Co. (Kansas), 139 Pacific, 428, p. 429, March, 1914.

RISK OF OPERATOR'S NEGLIGENCE NOT ASSUMED.

The statute of Indiana (sec. 8580, Burns, 1908) specifically imposes upon the operator of a mine certain duties to secure safety to the miners, and while it must be conceded that an employee who is engaged in making a dangerous place safe assumes the risk attending that particular service and at that particular place, yet he does not assume risks at other places where his work calls him or where he is directed to go, of which he has no knowledge and where the defects or dangers could only be observed by inspection, nor does he assume the risk occasioned by the operator's negligence.

Domestic Block Coal Co. *v.* Holden (Indiana Appeals), 103 Northeastern, 73, p. 76, November, 1913.

NEGLIGENCE OF FELLOW SERVANT—EFFECT.

EMPLOYEE OF PROHIBITED AGE—FELLOW-SERVANT RULE.

A boy under 16 years of age employed by a mine operator in violation of the statute of Kentucky, and without the consent of his father, is entitled to recover for injuries received while in the course of his employment in the mine, without proof of negligence on the part of the mine operator; and in an action by such youthful miner for injuries the fellow-servant doctrine can not be interposed as a defense.

Stearns Coal & Lumber Co. *v.* Tuggle (Kentucky), 161 Southwestern, 1112, p. 1113, January, 1914.

FELLOW-SERVANT RULE ABROGATED BY STATUTE.

The fellow-servant act of Colorado (R. S. 1908, sec. 2065) makes a coal-mine operator liable for the injury or death of a miner when in the exercise of due care, caused by the negligence of another miner, and in an action for the death of a miner it is sufficient to impose a liability upon the mine operator under the statute, to show that the death was caused by the negligence of a fellow-servant; and a judgment for damages will be upheld where the evidence shows the death was caused by the negligence of another miner.

National Fuel Co. *v.* Maccia (Colorado), 139 Pacific, 22, p. 23, March, 1914.

Under the fellow-servant act of Colorado that makes an employer liable for the injuries or death of an employee resulting from negligence of a coemployee, an employee does not under the statute, as a matter of law, assume the risk of the future unanticipated negligence of a coemployee.

National Fuel Co. *v.* Maccia (Colorado), 139 Pacific, 22, p. 24, March, 1914.

NEGLIGENCE OF MINE FOREMAN OR BOSS.

OPERATOR LIABLE—INSTANCES.
OPERATOR NOT LIABLE—INSTANCES.

OPERATOR LIABLE—INSTANCES.

FOREMAN REPRESENTS OPERATOR.

Under the statute of Pennsylvania, act of June 10, 1907 (Pa. Laws, 523), the mine foreman represents the operator and the operator is liable for injury to a miner resulting from the negligence of a foreman.

Philadelphia & Reading Coal, etc., Co. *v.* Keslusky, 209 Fed., 197, p. 198, November, 1913.

FAILURE OF FOREMAN TO WARN MINER.

A mine owner and operator is liable for the negligence of a mine foreman under the Pennsylvania statute where a miner in obeying the orders of the mine foreman was injured by an explosion of dynamite caused by the lamp on his cap igniting a squib attached to the dynamite that the mine foreman had inserted in the hole under which the miner was required to pass in carrying out the orders of the foreman, and where the forman negligently failed to warn the miner of the presence of the squib and dynamite in time to avoid the explosion and injury.

Philadelphia & Reading Coal, etc., Co. *v.* Keslusky, 209 Fed., 197, p. 198, November, 1913.

NEGLIGENCE OF FOREMAN—DANGEROUS PLACE.

The statute of Oklahoma requires a mine operator to provide a mine foreman and makes it his duty to examine every working place in the mine at least once every day and to securely prop such working place and to prevent miners from working in any unsafe place except for the purpose of making the place safe, and a mine operator is liable for an injury to a miner resulting from a violation or the failure to comply with these provisions, though such violation is due to the negligence of the mine foreman; and a judgment for damages for the death of a miner caused by such failure to comply with the statute will not be reversed on appeal because of an error in an instruction as to the contributory negligence of the deceased miner where the evidence showed not only a failure of the foreman to inspect the mine as required but that he put miners to work in the mine immediately after water was pumped out of the shaft before the shaft was dry and when he knew that the shaft was not in a safe condition, by reason of the mine having been recently filled with water and standing in that condition for months prior to the accident, and that timbers and props had fallen and had not been replaced and that recent blasting in the mine had weakened the roof, where it was also shown that the roof was 20 feet from the bottom of the drift and that the deceased miner was not required to and could not inspect the roof, and where such instruction though inaccurate or erroneous, when applied to the evidence before the jury, could not have mislead the jury to believe their duty was different from what it actually was.

Big Jack Min. Co. *v.* Parkinson (Oklahoma), 137 Pacific, 678, p. 681, December, 1913.

KNOWLEDGE OF NEGLIGENCE OF MINE FOREMAN.

Where a mine operator has knowledge through his superintendent or otherwise of the neglect of the certified mine foreman in performing a statutory requirement and that he has failed to furnish props to a miner on demand, as required by the statute, and the operator has knowledge of the dangerous condition of the mine by reason of such neglect of the mine foreman, he may he held liable for a consequent injury to a miner.

Peters *v.* Vesta Coal Co. (Pennsylvania), 90 Atlantic, 65, January, 1914.

FAILURE OF FOREMAN TO DISCOVER DANGEROUS ROOF.

If a clod or other hard substance in the roof of a mine constituted a dangerous condition, it is the duty of the mine examiner to discover such fact and mark the place, and if conditions in the mine are in fact dangerous the owner or operator can not excuse himself from liability for a willful violation of the mines and miners' act of Illinois if he fails to cause the places where the dangerous conditions exist to be marked, even though the mine examiner may have examined such places and in good faith believed that the conditions were not dangerous, and especially where it is known that a clod when it becomes exposed and is not supported is liable to fall in a certain length of time, but not right away.

Piazzi *v.* Kerens-Donnewald Coal Co. (Illinois), 104, Northeastern 200, p. 201, February, 1914.

NEGLIGENCE OF FOREMAN EMPLOYED BY OPERATOR.

The statute of Pennsylvania requires a mine operator to place the underground workings of his mine in charge of a competent mine foreman, and the operator is not liable for injuries resulting from the negligence of such mine foreman; but the statute does not prevent the mine operator from employing a mine foreman to perform services outside of the duties imposed by the statute, and if under such an employment a miner is injured by the negligence of the mine foreman while engaged in performing his duties under such a contract the mine operator is liable.

Calusky *v.* Lehigh Valley Coal Co., 212 Fed., 304, p. 306, March, 1914.

INCOMPETENT INSPECTOR—FAILURE TO INSPECT AND REPAIR.

Under the liability act of Alabama (Code, sec. 3910), if the duty of inspection is intrusted to a miner and is not, after reasonable time and opportunity are afforded, performed, and injury to another miner proximately results therefrom, the omission is negligence to liability, unless defeated by affirmative evidence; and the omission by one so intrusted to exercise, after reasonable time and opportunity are afforded, due care and diligence to make the necessary repairs and to remedy the known defect, and in proximate consequence thereof a miner is injured, such omission is negligence to liability, unless defeated by affirmative defense; but reasonable time and opportunity to discover or to repair after discovery are factors, and if either is absent negligence is not shown.

Espey *v.* Cahaba Coal Co. (Alabama), 64 Southern, 753, p. 755, February, 1914.

FAILURE TO INSPECT CABLE.

A court can not say as a matter of law that a mine operator is not liable for the death of a miner caused by the breaking of a cable used in drawing the miners out of the mine, on the ground that the operator had employed a certified mine foreman as required by the statute of Pennsylvania and had placed him in entire charge of the mine workings, where the evidence was contradictory as to whether or not the mine foreman was given entire charge of the mine workings and as to whether or not it was made a part of his duty to inspect the cable, and where an assistant foreman testified that he did not have charge of the cable but the cable was inspected by the engineer, and where it appeared that the engineer had no authority to inspect the cable and had no technical knowledge of cables.

Dodd *v.* Summit Branch Min. Co. (Pennsylvania), 88 Atlantic, 927, p. 928, June, 1913.

OPERATOR NOT LIABLE—INSTANCES.

FAILURE TO PROVIDE PROPS.

The statute of Pennsylvania (Pa. Laws, 52) makes it the duty of a mine foreman to see that all dangerous roofs are secured against falling and that sufficient props and timbers are sent into the working place of the mine when required for that purpose, and it is made the duty of the operator or his superintendent to keep on hand at the mine a full supply of all materials required, and where a mine operator has on hand the necessary timber for propping the roof he is not liable to a miner injured by the fall of the roof of his entry due to the negligence of the mine foreman in failing to see that the timbers were furnished to the miner.

Peters *v.* Vesta Coal Co. (Pennsylvania), 90 Atlantic, 65, January, 1914.

FAILURE OF FIRE BOSS TO DISCOVER GAS.

While section 7381 of the Remington and Ballinger Code requires the owner or operator of a coal mine to furnish a sufficient amount of ventilation, and requires that every working place shall be examined every morning by a competent person and a record of such examination made in a book kept at the mine for that purpose, yet the operator is still responsible for such further care as the common law imposes upon him, but neither the statute nor the common law makes a fire boss, one of whose duties was to make tests for gases or fire damp before firing shots, a representative of the operator in the matter of discovering the presence of gas or fire damp; but such a fire boss is a fellow-servant of the miner, and the operator is not liable for his failure to make the required tests for the presence of gas during the working hours, but such fire boss is regarded as a fellow-servant of the miner and the operator is not liable to the injury caused by the negligence or the failure of such fire boss to make the required tests with a view of determining the presence of gas.

Pacific Coast Coal Co. *v.* Brown, 211 Fed., 869, p. 873, February, 1914.

STATUTORY ACTION FOR WRONGFUL DEATH.

RIGHT OF ACTION FOR WRONGFUL DEATH.

The common law furnishes no remedy by civil action for the wrongful death of a person, and it is only by express statutory provision that such an action can now be maintained.

Maronen *v.* Anaconda Copper Co. (Montana), 136 Pacific, 968, p. 969, November, 1913.

ACTION FOR WRONGFUL DEATH—DEFENSES AVAILABLE.

In an action by heirs or next of kin against a mine operator for death by wrongful act or neglect, given by section 6486 of the revised codes of Montana, where the death was caused by the violation of another section of such revised codes imposing a criminal liability for its violation, the defendant is not limited to those defenses only that would be valuable to him in a criminal action in which he is defendant, in a prosecution by the State charging the unlawful killing, but in such an action a defendant may plead and prove the ordinary defenses available in actions for negligence.

Maronen *v.* Anaconda Copper Co. (Montana), 136 Pacific, 968, p. 970, November, 1913.

APPLICATION OF STATUTE.

Section 6486 of the revised codes of Montana gives to certain persons a right of action against another for wrongful death where a wrongful act or neglect was the proximate cause of the death, and the words of the statute, "wrongful act or neglect of another," imply actionable wrong or negligence toward the deceased and not a wrongful act or neglect toward the persons given the right to maintain the action; and such an action accordingly can only be maintained by the persons given the right to use where the decedent himself could have recovered damages had he survived the injury; and while the right of action given by this section to the heirs or personal representatives is independent of that which the deceased would have had in case of his survival, yet it is of the same character and depends upon the same facts.

Maronen *v.* Anaconda Copper Co. (Montana), 136 Pacific, 968, p. 970, November, 1913.

The action given by the Illinois statute (Laws of 1899, p. 300) for the wrongful death of a miner vests primarily in the widow, if there is one, and if not, then in the lineal heirs or adopted children, and in default of these, then in any other person or persons dependent for support on the deceased miner; and where a miner who lost his life in a coal mine left a father and mother and brothers and sisters the right of action under this statute vests in the father and mother alone, and as the right of action is purely statutory it was within the power of the general assembly in conferring the right to determine who should be authorized to bring the action and how the damages should be distributed, and in either case the right conferred is to recover the whole damages, and the statute authorizes but one action and one recovery for the entire loss and damage occasioned by the death.

McFadden *v.* St. Paul Coal Co. (Illinois), 105 Northeastern, 314, p. 315, June, 1914.

ACTION BY PARENT FOR DEATH OF SON—RECOVERY.

Under the statute of Iowa (Code, sec. 3471) providing that a father, or under certain circumstances the mother, may maintain an action for the expenses and actual loss of service resulting from the injury or death of a minor child, the word "expenses" has reference to the reasonable cost incurred for medical attendance, nursing, and including fit or suitable burial, and a general statement of the cost of funeral expenses, in the absence of any other evidence, will not justify the submission of the reasonable expenses thereof to a jury.

Carnego *v.* Crescent Coal Co. (Iowa), 146 Northwestern, 38, p. 39, March, 1914.

ACTION FOR WRONGFUL DEATH—COMPROMISE AND SETTLEMENT—EFFECT.

A father and mother as the sole heirs of a miner who lost his life in a coal mine may sue the operator for damages under the Illinois statute (Laws of 1899, p. 300), and they may settle and compromise such action while pending and release the cause of action, and such a release is a bar to any subsequent action brought by an administrator of the deceased miner under the act of 1853, this being the general act authorizing an action for death by wrongful act.

McFadden *v.* St. Paul Coal Co. (Illinois), 105 Northeastern, 314, p. 315, June, 1914.

MINES AND MINING OPERATIONS.

NEGLIGENCE OF OPERATOR.

PLEADING AND PROVING NEGLIGENCE—PRESUMPTIONS.

PLEADING NEGLIGENCE—SUFFICIENCY OF PLEADING—USE OF EXPLOSIVES.

In an action by a miner for injuries caused by an explosion of dynamite it is sufficient for the complaint to charge the defendant's negligence in having more than 3,000 pounds of explosives in the mine, in having explosives stored in a place in the mine where escape would be cut off in case of an explosion, in having explosives stored at and near the shaft, imperiling the lives of persons working in the shaft in case of an explosion, and in the method used for thawing dynamite in that electricity was used in such manner and to such a degree that the dynamite being thawed was heated to excess; but the plaintiff was not required to prove negligence in all the particulars alleged, and it was sufficient if the evidence introduced established the defendant's negligence in any of the particulars, thereby causing the injury complained of.

West Lake *v.* Keating Gold Min. Co. (Montana), 136 Pacific, 38, p. 40.

SPECIFIC NEGLIGENCE MUST BE PLEADED.

An allegation in a complaint in an action for an injury to a miner to the effect that the foreman directed the plaintiff and another miner not to remove a large rock from its place where it had fallen from a hanging wall in the mine, and to leave all waste matter, including the rock in the stope, is not sufficient to charge the defendant operator with any specific act of negligence where it appeared from the evidence that the large rock, after it had so fallen and while the plaintiff and the other miner were taking out the mining ore from the stope, rolled over upon the plaintiff's foot, causing the injury complained of.

Knauff *v.* Highland Dev. Co. (Oregon), 136 Pacific, 846, p. 847, December, 1913.

An injured miner in an action for damages is not required to allege in his complaint the specific acts of negligence of omission or commission on the part of the operator, but when he undertakes in his complaint to define the particular negligence which caused the injury his declaration must be tested by these special allegations in that respect, and having done so the proof must correspond to these allegations or he can not recover.

Wyoming Coal Min. Co. *v.* Stanko (Wyoming), 138 Pacific, 182, p. 183, February, 1914.

USING DEFECTIVE APPLIANCES—PLEADING.

In an action by an injured miner caused by defective brakes on coal cars, an allegation in his complaint to the effect that the operator did not furnish or provide safe machinery and appliances with which to work, and did not repair the brake and appliances upon its coal cars, and did not exercise reasonable care in the furnishing of such coal cars and appliances, and that if the operator had exercised due care and diligence in the inspection and repair of its coal cars the same would have been in safe condition; and a further allegation to the effect that at the time of furnishing such coal cars for use in its mine the operator knew, or by the exercise of proper care would have known, that such coal cars and the brakes thereon were in disrepair and dangerous and unsafe, and that by reason of the premises the plaintiff was injured, is a sufficient charge of negligence; in failing to repair the brake and in negligently furnishing such unrepaired cars the operator violated its duty to furnish reasonably safe appliances, and each and all the allegations direct the attention to the matter of repair, but the specific allegations that the cars were in disrepair negatives the idea that they were originally defective or not sound and good.

Wyoming Coal Min. Co. *v.* Stanko (Wyoming), 138 Pacific, 182, p. 183, February, 1914.

SUFFICIENCY OF SPECIAL FINDINGS.

In an action by a miner for injuries caused by the alleged negligence of the operator in its failure to examine and inspect the coal cars and thereby discover their unsafe condition, a finding by the jury to the effect that the cars had been in disrepair for some definite length of time before the accident would not be sufficient to entitle the plaintiff to recover in the absence of a finding that the operator had knowledge of the defective condition of the cars, or a finding to the effect that such defect existed for a sufficient length of them under all the circumstances for the operator to have discovered the defects by the exercise of reasonable diligence.

Wyoming Coal Min. Co. *v.* Stanko (Wyoming), 138 Pacific, 182, p. 183, February, 1914.

SUFFICIENCY OF COMPLAINT BY INJURED MINER.

A complaint by an injured miner against a mine operator after averring the relationship between plaintiff and the defendant is sufficient where it avers that the plaintiff while in the discharge of his duty under his employment was riding on a car in a certain entry of the mine and was thrown from such car, dragged and crushed and permanently injured, all of which was proximately caused by a defect in the condition of defendant's ways, works, machinery, or plant, in that the roof of the mine at the point where plaintiff was injured in such entry was so defective that it caught the plaintiff between the car and such roof, inflicting the injuries complained of.

Chocktaw Coal & Min. Co. *v.* Moore (Alabama), 63 Southern, 558, p. 559, November, 1913.

INJURY FROM CAR UPSETTING—PLEADING AND PROOF.

A miner injured while loading a car which he himself was filling by the car tipping over on him is entitled to recover damages on the ground of alleged negligence in that the operator failed to put under the rails of the track a sufficient number of ties to hold the track in place and failed to properly nail or fasten the rails to the ties, thereby causing the car as it was loaded with coal or dirt to tip over; and a recovery can not be denied because the proof shows that the specific negligence causing the injury was the failure of the operator to put another tie at or near the end of the rails, causing the car to tilt endwise rather than sidewise, caused by the track going down at the end rather than becoming lower upon one side than upon the other, as alleged; and it can not be regarded as a fatal variance where the general allegation of the pleading was sufficient to show that the injury was caused by the operator's failing to furnish a safe and secure track on which to operate the cars.

Thorton *v.* American Zinc, Lead & Smelting Co. (Missouri Appeals), 163 Southwestern, 293, p. 294, November, 1913.

PROOF OF NEGLIGENCE.

In an action against a mine operator for damages for the death of a miner on the ground of alleged negligence it is not sufficient as a basis of recovery merely to prove negligence and injury, but it is necessary to show that the proven injury was the natural and proximate result of the proven negligence; and the mere proof of the negligent removal of a prop supporting the roof of a mine is insufficient to sustain an action where it appeared that the prop was 7 or 8 feet from the rock that fell, and where there was a hill seam between the prop and the rock and the break stopped at the hill seam between the prop and the rock, and where it appeared that the prop was removed on Saturday and the accident took place on the following Tuesday.

Cooke-Jellico Coal Co. *v.* Richardson (Kentucky), 161 Southwestern, 537, p. 539, December, 1913.

EVIDENCE AS TO CAUSE OF EXPLOSION.

In an action by a miner for injuries caused by an explosion of dynamite it is proper to show, under an allegation of negligence in the method of thawing dynamite, that the dynamite was thawed by electricity and electric bulbs inserted in the thawer, and that by reason thereof the dynamite was frequently overheated and when in such condition would explode from a jar or concussion such as would be caused from the bursting of an electric-light bulb, and that in the thawing of the dynamite moisture sufficient might be generated to cause an electric-light bulb to explode, the concussion being sufficient to explode the overheated dynamite. The admissibility of such evidence is based on the proposition that if the collapse of an electric bulb was a matter to be reasonably anticipated, and if such a collapse would suffice to explode dynamite heated to a degree possible in a thawer, then it was negligence in the operator to employ a system of thawing in which these conditions might occur.

West Lake *v.* Keating Gold Min. Co. (Montana), 136 Pacific, 38, p. 43, October, 1913.

EVIDENCE AS TO THE USE OF ELECTRICITY FOR THAWING DYNAMITE.

In an action by a miner for injuries caused by an explosion of dynamite under a charge of negligence in the method of thawing dynamite by electricity, evidence is inadmissible to show that electricity was not employed in other or similar mines as a thawing agency; but such evidence is admissible under a general charge that the use of electricity for thawing dynamite is negligence, without regard to the manner of its use.

West Lake *v.* Keating Gold Min. Co. (Montana), 136 Pacific, 38, p. 43, October, 1913.

EXPERT EVIDENCE AS TO METHODS OF THAWING DYNAMITE.

In an action by a miner for injuries caused by an explosion of dynamite where the method of thawing the dynamite was shown and where the evidence showed that in the method used the dynamite was frequently overheated to such extent that it was dangerous to use, it is competent to show by the opinions of qualified persons whether the method employed for thawing the dynamite was safe or otherwise.

West Lake *v.* Keating Gold Min. Co. (Montana), 136 Pacific, 38, p. 43, October, 1913.

PROOF OF NEGLIGENCE—CIRCUMSTANTIAL EVIDENCE.

It is the duty of a mine operator to furnish its miners a safe working place, and it is sufficient where an operator directed a miner to work in a room in which no work had been done for several days and where, after draining out the water that had collected in the room, the miner undertook in the discharge of his employment to dig up a ledge of coal in the bottom and near the face of the room, and while so digging his pick struck dynamite or other explosive, which was thereby exploded and by reason of which the miner was injured, to show that the operator did not furnish the miner a safe working place as was its duty; and direct proof of negligence in such a case is not required but may be established from the circumstances and from the fact that the miner was put to work in a room of a mine in which unexploded charges had been left. That there is a well-known practice of using explosives in mining coal, that an explosion did occur when the miner struck into the coal with his pick, are sufficient circumstances to show a prima facie case of negligence and to establish the negligence of the operator in failing to furnish the miner a safe working place.

Broseghini *v.* Sheridan Coal Co. (Kansas), 139 Pacific, 1025, p. 1026, April, 1914.

QUESTION OF FACT.

The owner and operator of a coal mine is not as a matter of law liable for an injury to a slate picker at a coal tipple who was called from his regular duty in the morning before daylight to assist in adjusting a belt to a large pulley wheel operated by electricity and was injured by a sudden and repeated starting of the wheel, but the question of negligence in such case is one of fact to be determined by a jury in connection with all the facts and circumstances of the case.

Valley Camp Coal Co. *v.* Kucewicz, 211 Fed., 953, p. 954.

In an action by a miner for personal injuries ordinarily the question of negligence of the mine operator is one for the jury, and it is only when the facts are undisputed and are such that reasonable men can fairly draw but one conclusion from them that the question of negligence is ever considered one of law for the court.

Carney Coal Co. *v.* Benedict (Wyoming), 140 Pacific, 1013, p. 1015, May, 1914.

PRESUMPTION OF NEGLIGENCE.

In an action against a mining corporation for the death of an employee caused by an electrical current while attempting to use a pump operated by electricity in the defendant's plant, while the question of negligence on the part of the mining company is a question of fact to be determined by the jury, yet where the cause of the death can not be certainly shown, and where it can not be attributed to mistake, neglect, or misconduct on the part of the deceased, and where the pump, the thing which caused the injury, was shown to be under the exclusive control of the defendant, a presumption of negligence arises and the circumstances afford reasonable evidence in the absence of explanation by the defendant that the accident arose from want of care.

Hill *v.* Pacific Gas & Electric Co. (California), 136 Pacific, 492, p. 499, November, 1913.

In an action by an employee who was injured while assisting in drilling an oil well, where the injury was caused by the fall of the roof of a derrick, and where it appears that the roof fell because of the giving away of certain nails driven through the end of the ridgepole into the derrick timbers, and where it appears that the derrick and machinery were being used by the oil company in the ordinary and proper way and while no defectiveness or insecurity of the roof or its fastenings had been observed from casual observance, yet the company is not excused by the mere fact that the derrick had been constructed in the usual manner and was at the time of its construction in a safe condition; but its duty was to use due care to maintain such condition, and that the falling of the roof under such circumstances and the consequent injury to the employee was sufficient to establish a prima facie case of negligence, and under the circumstances the jury had a right to find that the employee received his injury by reason of negligence of the employer and while he was engaged in his ordinary duties and without fault or negligence on his part.

Ingalls *v.* Monte Cristo Oil & Development Co. (California), 139 Pacific, 97, p. 100, March, 1914.
Broseghini *v.* Sheridan Coal Co. (Kansas), 139 Pacific, 1025, April, 1914.

INJURIES FROM ESCAPING OIL—JUDICIAL NOTICE.

In an action by the owner of cattle killed and injured by drinking water into which oil had escaped and flowed from the pipe line of the defendant company the court can not take judicial notice that the oil was poisonous or otherwise of such a character as would when drunk result in the injury or death of the cattle, and in the absence of proof to the effect that the oil was poisonous or would produce death or injury to cattle drinking water impregnated with the oil there can be no recovery.

Texas Co. *v.* Earles (Texas Civil Appeals), 164 Southwestern, 28, p. 30, February, 1914.

ADMISSABILITY OF DECLARATIONS AS TO CAUSE OF INJURY.

In an action against a mine operator for the death of a car driver caused by being caught between a loaded car and the walls of the tunnel or haulage way, statements as to the cause of the injury made by the injured miner shortly after the accident and while he was still lying at the place where the injury was inflicted and while suffering great bodily pain are admissible in evidence as a part of the res gestae, as in such case it is reasonable to conclude that the injured miner had opportunity to deliberate and design, such as to take from his utterances the impress of spontaneity.

Smith *v.* Stoner (Pennsylvania), 89 Atlantic, 795, p. 797, January, 1914.
Sams *v.* Grey (Kentucky), 161 Southwestern, 553, December, 1913.

DEGREE OF CARE REQUIRED.

CARE AND DILIGENCE—DEGREE.

A far higher degree of care and diligence is demanded of the mine operator who places his miners at work digging coal beneath the overhanging masses of rock and earth in the mine than of the master who places his employees at work on the surface of the earth where such dangers are not to be apprehended; and a reasonably prudent man would exercise greater care and watchfulness in the former than in the latter case, and in such cases the rule applies that the greater the danger a reasonably intelligent and prudent man would apprehend the higher is the degree of care and diligence the master must exercise.

Big Hill Coal Co. *v.* Clutts, 208 Fed., 524, p. 526, November, 1913.

The duty of a mine operator to use ordinary care to provide a reasonably safe place for a miner to work necessitates the exercise of more care than would be required to discover defects in the roof of such a character as to be readily discoverable by ordinary inspection.

Victor-American Fuel Co. *v.* Peccarich, 209 Fed., 568, p. 571, November, 1913.

It is the duty of an operator of a coal mine to exercise reasonable care and prudence to provide his servants with a reasonably safe place in which to work, with reasonably safe material upon which to work, and suitable and competent fellow-servants; but it is not error for a court in an action by an injured miner against a mine owner for damages to instruct the jury to the effect that it was the duty of the defendant to furnish the plaintiff a reasonably safe place in which to work, reasonably safe appliances and machinery with which to work, and a reasonably safe track over which the cars were to be hauled, and a failure to do so was negligence for which he was liable, as it was not the intention of the court by such instruction to impose upon the operator any duty higher than that of the use of ordinary or reasonable care under all the circumstances to furnish such safe place and appliances.

Great Western Coal & Coke Co. *v.* Malone (Oklahoma), 136 Pacific, 403, p. 406, November, 1913.

NEGLIGENCE AND ORDINARY CARE DEFINED.

Negligence is defined as the doing of a thing that a reasonably prudent person would not do under the circumstances surrounding him at the time, or it is the omission to do a thing that a reasonably prudent person would do under the circumstances. The degree of care required in any given case, to avoid the imputation of negligence, is ordinary care, and the law interprets ordinary care to be that degree of care which a person of ordinary prudence under the particular circumstances is presumed to exercise to avoid injury, and such care is required to be in proportion to the danger to be avoided and the fatal consequences that may result from neglect.

Shirley Coal Co. *v.* Moore (Indiana), 103 Northeastern, 802, p. 804, January, 1913.

EXTENT OF LIABILITY.

A mine operator is not an insurer of the safety of his miners, but it is his duty to use ordinary care for the miners' safety, and he is liable where a miner is injured by a defect in the place of work, when the operator knows, or by ordinary care should have known of the defect.

Williamson *v.* Bluegrass Flourspar Co. (Kentucky), 160 Southwestern, 920, p. 921, November, 1913.

MAINTAINING DANGEROUS PLACE.

DUTY TO FURNISH SAFE WORKING PLACE NONDELEGABLE.

It is the duty of a mine operator to furnish a safe working place for his miners in which to work and it is his duty to continue to keep the place safe, and this duty is one which can not be delegated by the master so that the employee engaged to do the work of making the premises safe is to be treated as a fellow-servant of those who are enployed and engaged in the general work for which the premises are intended.

Panela *v.* Castile Min. Co. (Michigan), 144 Northwestern, 528, p. 533, December, 1913.

The rule that an employer owes to his employee the nondelegable duty to exercise reasonable care to furnish his employee a reasonably safe place to work applies to mining operations, and the peculiarly dangerous conditions under which mining operations are carried on make the duty of providing a safe place to work unusually pertinent as the more hazardous the employment the greater would be the care.

Dashner *v.* Hocking Min. Co., 212 Fed., 628, p. 631, April, 1914.

It is the duty of a mine operator to use reasonable care to furnish a miner a reasonably safe place in which to work, and this duty being material in character can not be delegated, and the person to whom such duty is intrusted, or who as a part of his work assumes to do it with the operator's knowledge and consent, is not a fellow-servant with the miner engaged simply as such, having no duty to perform as to the roof of the mine in which he was working.

Looney *v.* Garfield Coal Co. (Iowa), 147 Northwestern, 129, p. 130, May, 1914.

SAFE PLACE—APPLICATION OF DOCTRINE.

A mine operator is not liable for the death of a miner performing the work of a "hitch cutter" whose duty consisted in cutting holes called "hitches" in the rock of the footwall of a stope or tunnel of the mine for the purpose of receiving the lower ends of pieces of timber set upright and driven tight against the top or hanging wall or stope to prevent rock from falling, where it was the duty of such hitch cutter to assist in making the working place safe and to examine and see that everything was safe before going to work, and in case the place was not safe he, with his assistant, should take time to make it safe, where men were furnished to assist in making such place safe, and where it appeared that the deceased miner and his partner were fully convinced that the place was safe to go to work in and the head timberman informed the deceased miner that he and his partner could go to work as everything was safe, as in such case the miners were authorized and were expected to judge for themselves as to the safety of the place and were competent to do so and placed no reliance upon the judgment of any other employee, and under the circumstances the doctrine of safe place and the duty of the operator in that behalf does not apply.

Andrews v. Tamarack Min. Co. (Michigan), 146 Northwestern, 394, March, 1914.

CONTINUING DUTY TO KEEP WORKING PLACE SAFE.

The duty of a mine operator to use reasonable care to provide reasonably safe places for his servants to work is a continuing one and the mine operator does not discharge his duty in this regard by providing a safe place in the first instance and then remaining passive, but he must supervise, examine, and inspect as often as custom and experience require, and at all times use ordinary care to keep the working places in his mine in a reasonably safe condition where this duty does not rest upon the miner himself.

Shirley Coal Co. v. Moore (Indiana), 103 Northeastern, 802, p. 804, January, 1913.

LIABILITY WHERE ACCIDENTS CAN NOT BE ANTICIPATED.

A mine operator is chargeable with knowledge of all dangers to miners in the bottom of a shaft which are liable to result from the methods employed in timbering the shaft, which would be known to a person of reasonable skill and experience in the work and business of timbering shafts; and if reasonable care was not used to protect miners from injuries due to objects falling down the shaft it would not excuse a mine operator that he had given instructions to the timbermen to use such care for the miner's protection, as this was a duty that the operator could not impose on any other person so as to escape responsibility, but under such circumstances a mine operator can not be held liable as for negligence in omitting to guard against accidents that are not likely to happen and that even a prudent man would not have been likely to anticipate, and where the injury occurs to a miner by the falling of timbers used in timbering a shaft it is a fair question to be submitted to the jury whether the accident can be said to be one which even a prudent man would have been likely to anticipate.

Kaaro *v.* Ahmeek Min. Co. (Michigan), 146 Northwestern, 149, p. 155, March, 1914.

INJURY FROM FALL OF ROOF—BLASTING OUT PILLARS.

A mine operator is liable for. the negligence of its employees in blasting out pillars and thereby loosening and making dangerous the roof of a mine and causing an injury to a miner who had been directed to wall up a certain entry connecting the mine with an old mine to keep out black damp emitted from fire in such old mines though the injured miner had temporarily left his work and gone some distance to adjust and replace a temporary curtain extended across such entry to keep out such fire damp and which had been displaced by reason of such blasting.

Victor-American Fuel Co. *v.* Peccarich, 209 Fed., 568, p. 571, November, 1913.

DANGEROUS ROOF—DUTY TO WARN MINER.

Where a mine operator has knowledge, or might obtain knowledge by an inspection, of a defective condition of roof of his mine where one of his miners is required to work, which renders the place unsafe and dangerous, and the defect is such that it can not be readily detected by the miner, the operator is bound to inform him of the situation, and a failure so to do will make him liable to respond in damages to the miner if he is injured by reason of the defective condition of his working place.

Domestic Block Coal Co. *v.* Holden (Indiana Appeals), 103 Northeastern, 73, p. 75, November, 1913.

STORING EXPLOSIVES.

In an action by a miner for injuries caused by an explosion of dynamite it is sufficient to allege that the dynamite was negligently stored at a place where, should an explosion occur, the life of the plaintiff and other persons working in that shaft would be imperiled, as such an allegation is sufficient to invoke the doctrine of the operator's obligation to use reasonable care to furnish his employees with a reasonably safe place in which to work; and this is particularly true where all the facts relating to the storing, such as the particular point where the plaintiff was working, the precise place where the dynamite was stored, with the stated distance from the thawer in which the dynamite was being heated, and where it is clearly made to appear that the place where the plaintiff was working was not a safe place if an explosion occurred.

West Lake *v.* Keating Gold Min. Co. (Montana), 136 Pacific, 38, p. 41, October, 1913.

TIMBERING.

After a coal mine is once opened and timbered it is the duty of the owner or operator to use reasonable care and diligence to see that the timbers are properly set and to keep them in proper repair.

Big Hill Coal Co. *v.* Clutts, 208 Fed., 524, p. 526, November, 1913.

FAILURE TO TIMBER—PROXIMATE CAUSE.

In an action by a miner for injuries received while working in his stope, an allegation that the injury was received by reason of the mine operator's failure to timber the stope is not sustained where the proof shows that the absence of such timbering was not the proximate cause of injury complained of, where the evidence showed that the rock producing the injury had fallen from the hanging wall long before the injury was received.

Knauff *v.* Highland Dev. Co. (Oregon), 136 Pacific, 846, p. 847, December, 1913.

DUTY TO TIMBER MINE—MAKING PLACE SAFE.

A mine operator must timber up his mine and use ordinary care to keep it reasonably safe for the use of his miners; but he must have men to so timber the mine, and when a mine operator sends in one set of men to timber up a mine he is not required to first send another set of men to make the place safe for them; and men engaged in such work must understand that they are putting in the timbers to make the mine safe, and a mine operator is not liable for the death of a timberman sent with others to timber up a part of the mine and to make it safe for miners to work, where the danger was a hidden one unknown to the mine operator and not discoverable by ordinary care.

Williamson *v.* Bluegrass Fluorspar Co. (Kentucky), 160 Southwestern, 920, p. 923, November, 1913.

INSPECTION OF ENTRIES.

A mine operator owes the miner the duty of exercising reasonable care to make the entries in his mine reasonably safe, where the miner himself is not required to inspect or keep safe such entries; and this rule applies to miners employed by an independent contract under contract with the operator to mine coal, where his employees are required to pass through the entries maintained and inspected by the operator.

Big Hill Coal Co. *v.* Clutts, 208 Fed., 524, p. 527, November, 1913.

FAILURE TO FURNISH SAFE PLACE—INJURY TO MINER.

It is the duty of a mine operator to furnish his miners a reasonably safe place in which to perform their work and to take the proper precautions and use reasonable care to guard against injuries to the miners, and if injury occurs on account of the failure of the mine operator to discharge this duty and the injured miner is without fault the operator will be liable.

Shirley Coal Co. *v.* Moore (Indiana), 103 Northeastern, 802, p. 804, January, 1913.

LIVE ELECTRIC WIRES.

A mine operator is guilty of actionable negligence in case of resulting injury in the use of electricity in his mine by means of an uninsulated wire or other appliances where he knows any person may for any reason come in contact with it without knowledge of the use to which the applicance is devoted, and such a use is tantamount to the placing of a deadly mine or trap, however free the user may be from wrongful intent, and the silent, latent, deadly electrical power of a live wire, giving no warning of its presence through hearing, sight, or other faculty, renders it so highly dangerous that its use carries an extremely high degree of care.

Humphreys *v.* Raleigh Coal & Coke Co. (West Virginia), 80 Southeastern, 803, p. 805, February, 1914.

A mine operator using electricity must provide against all probable contingencies and every possibility that can be reasonably foreseen and anticipated, and if he knows any person is liable in any way or for any reason, whether on a mission or enterprise of business or pleasure, to come in contact with the heavily charged electrical wire he is using, he must insulate it, unless insulation is impossible by reason of incompatibility with the use to which it is devoted; and it is wholly immaterial that the place in which such a wire is used was not a way or passage or place of ordinary work, but where, in the instant case, such uninsulated wire was placed in the break-through and air course, not passageways or places of ordinary work, but where there was occasion for miners to enter them.

Humphreys *v.* Raleigh Coal & Coke Co. (West Virginia), 80 Southeastern, 803, p. 806, February, 1914.

DUTY TO PROP ROOF—LIABILITY FOR INJURY.

Where it was the duty of an injured miner to prop the roof and make his place safe, he can not recover against the mine operator for an injury caused by his failure to perform this duty; but if the roof was in such condition that it was the duty of the operator to timber and make it safe, and by reason of the operator's failure to do so the miner while exercising ordinary care for his own safety was injured and killed, the fact that the company's foreman told the decedent to do the propping, when it was not his duty to do it, will not relieve the mine operator from liability.

Duncan Coal Co. *v.* Thompson (Kentucky), 162 Southwestern, 1139, p. 1140, February, 1914.

FAILURE TO PROP—MEANING OF "BAD PLACES."

A contract between the United Mine Workers and an Employers' Association is binding on a coal company that is a member of such association, and a "bad place" within the meaning of such a contract is a place in the roof which can not be made reasonably safe by the ordinary propping usually done by the miner himself, and if the roof in a room where a miner is employed was a "bad place" and if such condition was known to the mine operator, its agents and servants charged with the duty of timbering the roof, or by the exercise of ordinary care could have been known to them, and was not known to the miner, and was not so obviously dangerous as to charge a person of ordinary prudence with notice thereof, and the operator failed to timber the roof, and by reason thereof a miner, while exercising ordinary care for his own safety, was injured and killed, then the mine operator is liable in damages; but if the roof was an ordinary roof, one that could be made reasonably safe by the ordinary propping usually done by the miner himself, then the operator would not be liable.

Duncan Coal Co. *v.* Thompson (Kentucky), 162 Southwestern, 1139, p. 1140, February, 1914.

DANGEROUS ENTRY.

A mine operator is liable to a miner injured by a fall of rock from the roof of a room neck, the passageway to and from the room in which the miner was working, and which was in the care and keep of the operator, and he was bound to exercise ordinary care to keep the place reasonably safe, and where the operator was notified of the danger inhering in the roof two days prior to the time of the injury.

Gambino *v.* Manufacturers' Coal & Coke Co. (Missouri Appeals), 164 Southwestern, 264, p. 266, February, 1914.

HIDDEN DANGERS.

A person employed by a mining company to do outside work at its colliery is entitled to recover for an injury on the ground of negligence of the operator where on the morning of the accident he was directed by the foreman to go with him to another part of the works and in following the foreman along a well-defined path used by the workmen that led over a culm bank he was injured by stepping into an open barrel of hot water sunk to within 2 inches of the surface of the bank and located in or close to the edge of the path, where it appeared that he had not before been over the path and did not know of the location of the barrel, and did not at the time see it because he was blinded by a sudden escape of steam from the barrel or from pipes that led to it.

Susko *v.* Harleigh-Brookwood Coal Co. (Pennsylvania), 90 Atlantic, 716, p. 718, March, 1914.

FAILURE TO INSPECT ROOF OF TRAVELING WAY.

Where a mine operator was aware of the existence of a pothole in the roof of a tunnel for a sufficient time before the accident resulting in an injury to a miner, and failed to make an inspection of the roof and the pothole by sounding or otherwise in order to detect the looseness of the rocks and to determine whether the rock in the pothole had become loose by reason of the action of the air, water, vibrations caused by blasting, or otherwise, the operator is liable for such neglect for an injury caused by the rock falling from the pothole and injuring a miner using such traveling way.

McInness *v.* Republic Coal Co. (Montana), 140 Pacific, 235, p. 237, April, 1914.

DANGEROUS EXCAVATIONS.

A miner and prospector who enters upon the public domain and prospects for minerals and who took possession of certain phosphate claims and dug holes and pits thereon, as required by the United States statute in order to hold his location, is not chargeable with negligence where cattle and live stock stray upon and trespass on such mining claim and are injured or killed by falling into such pit and excavations, as a locator or owner of a mining claim is not required by statute to fence or otherwise protect such excavations and shafts, and he is expressly authorized by the United States statutes to make such excavations in the development and possession of his claim.

Strong *v.* Brown (Idaho), 140 Pacific, 773, p. 774, May, 1914.

UNSAFE PLACE—OPERATOR DIRECTING MINER.

Where a mine foreman with miners went to work in a room neck in a mine and the foreman directed the miner to cut a hitch in one end of the room and directed another workman to cut another hitch on the opposite side, these being places cut in the coal or sides of the mine in which to rest the end of the timber, and one miner detecting a piece of loose slate was assisted in taking it down and it was then suggested that they investigate to see if there was any other loose slate, and whereupon the foreman took his pick and sounded the slate and said it was all right, and thereupon directed the miner to go on and cut the hitch, and as the miner proceeded and after striking a few licks was injured by the slate falling upon him, the miner injured under such circumstances is entitled to recovery under a rule that where one is working under the immediate and direct orders of his superior, and that superior, after investigation, expresses an opinion that the place is safe, or directs the employee to proceed with the work, the employee has a right to rely upon the presumed superior knowledge of the employer and proceed with the work unless the danger is so obvious and apparent as that no reasonable man, in the exercise of a fair judgment for his own safety, would continue to work in it, even under the orders of his master.

Bracken *v.* Lam Coal Co. (Kentucky), 165 Southwestern, 686, April, 1914.

A coal miner in an action for damages for injuries received by falling rock from the roof of an entry constructed by him is entitled to recover on grounds of the alleged negligence of the operator where the proof shows that the pit boss was authorized to direct the injured miner how to perform the work and that he omitted timbering as directed by the pit boss, until the brushing had been completed, and where it appears that the omission to timber as the work progressed might have been the proximate cause of the injury.

Williams *v.* Craig Dawson Coal Co. (Iowa), 146 Northwestern, 735, p. 736, April, 1914.

NEGLIGENCE NOT PROXIMATE CAUSE OF INJURY—NO LIABILITY.

While a mine operator may be negligent in failing to keep the roof of an entry in his mine in a reasonably safe condition, such negligence can not be regarded as the proximate cause of an injury where the miner knew of the danger and with such knowledge used the entry and was injured by the falling of slate from the roof, where the miner was not required to use the entry or pass through it at the time he received the injury.

Elliott *v.* Greenville Coal Co. (Kentucky), 167 Southwestern, 424, p. 425, June, 1914.

EVIDENCE AS TO SUBSEQUENT CONDITION OF MINE.

In an action for damages by a miner for being overcome by gas on the ground of the alleged violation of the statute on the part of the mine operator in failing to keep the mine ventilated as required by the statute of Kentucky, the report of the mine inspector is admissible in evidence though made 17 days after the accident, where the plaintiff himself proved by the operator's mine superintendent that the condition of the air at that time was practically the same as it was immediately before and after the plaintiff's injury.

Mt. Morgan Coal Co. *v.* Shumate (Kentucky), 163 Southwestern, 1099, p. 1100, March, 1914.

WASTE IN STOPE.

A mine operator is not guilty of actionable negligence in leaving waste matter in a stope, and if it was the mine operator's duty to remove such waste from a stope, or if it was negligence to leave it in the stope, an injured miner complaining of such acts must allege and prove such duty or negligence.

Knauff *v.* Highland Dev. Co. (Oregon), 136 Pacific, 846, p. 847, December, 1913.

SUPERIOR SERVANT—PERSONAL LIABILITY.

Where a mine operator is guilty of negligence in failing to furnish a miner a reasonably safe place in which to work, a superior officer acting on behalf of the mine operator who fails to make an inspection or who fails to exercise ordinary care to see that the place is safe and directs a miner to proceed to work in such dangerous place is liable, together with the mine operator, for an injury resulting to the miner, under the rule that a superior officer is generally and severally liable with the common master for a failure to perform personal duties, whether of misfeasance or nonfeasance, which failure results in injury to one to whom the duty is owing; but notwithstanding this rule it must be observed that such superior servant is not liable for the failure of the mine operator to furnish the miner a safe working place, but his liability starts with the failure to make the proper inspection after an explosion for the purpose of discovering whether the miner would be put in danger from falling material.

Evans Chemical Works *v.* Ball (Kentucky), 167 Southwestern, 390, p. 394, June, 1914.

Ohio Valley Coal & Min. Co. *v.* Heine (Kentucky), 167 Southwestern, 873, p. 874, June, 1914.

UNSAFE PLACE—MINER OBEYING INSTRUCTIONS.

A miner in an iron mine whose duty it was to mark the quantity of ore the miners brought in and help the trammer turn the car on the turntable, keep the table free from dirt, and open the door of the car may recover for injuries on the ground of alleged negligence of the operator in failing to furnish a safe place to work, where while performing his ordinary duties the shift boss ordered him to go down a chute and loosen ore which had become clogged in the chute by pounding on the partition between a raise in the mine, and for this purpose a rope was tied around his body and he was lowered down the larger side of the raise and with a heavy hammer proceeded as instructed to pound upon the dividers, and while so engaged and without warning of the danger the clogged ore started to run into the opposite compartment when the ore chute broke through, and the ore carrying some of the dividers fell through the opening thus made upon the miner, causing the injury for which he sues.

Ranta *v.* Newport Min. Co. (Michigan), 147 Northwestern, 609, p. 610, June, 1914.

LIABILITY OF PIPE LINE COMPANY.

A pipe line company transporting oil through the ground is liable for damages for injury and death of cattle caused by drinking water poisoned by oil escaping and flowing into and down a creek in the pasture where the cattle were kept, regardless of the question and in the absence of proof of negligence on the part of the oil company in the construction or maintenance of its pipe line.

Texas Co. *v.* Earles (Texas Civil Appeals), 164 Southwestern, 28, p. 29, February, 1914.

USING DEFECTIVE APPLIANCES.

DEFECTIVE TRACK.

In an action by a miner for injuries occasioned by the car on which he was riding jumping from the track, due to the alleged defective condition of the track, together with the excessive speed of the car, it is not sufficient to relieve the operator from liability for negligence by proof that the engineer in charge did not know of the defective condition of the track.

Great Western Coal & Coke Co. *v.* Malone (Oklahoma), 136 Pacific, 403, p. 405, November, 1913.

DEFECTIVE TRACK—PROXIMATE CAUSE.

In an action by a miner for injuries caused by the derailment of a coal car on which he was riding due to the alleged defective condition of the track and to the excessive speed at which the cars were run, the plaintiff is not required to show that the defective condition of the track alone was the proximate cause of the injury.

Great Western Coal & Coke Co. *v.* Malone (Oklahoma), 136 Pacific, 403, p. 405, November, 1913.

HOISTING AND SIGNALING APPARATUS.

It is the duty of a mine operator to maintain a hoisting and signaling apparatus and the machinery connected therewith in a condition suitable to prompt action and service and to have the same so arranged and in such working order as they will promptly respond to signals given from the bottom of the shaft; and where miners were working in a shaft and desired to leave on account of impending danger and the usual and proper signals were given, by means of the apparatus provided, the operator must be liable for a resulting injury where the insufficiency of the signaling apparatus prevents a response by the man operating the hoist or cage in the shaft, if the failure to respond is due to some fault, defect in, or some failure of the machinery or apparatus in use; and in an action by a miner injured under such circumstances he is not required to point out the particular fault, defect, or cause of failure, and he can not be reasonably expected to know whether the signals were received at the surface, whether the apparatus for signaling failed, whether an employee disregarded them if received, or whether in attempting to send down the cage or car in answer to the signals some part of the other machinery or apparatus was found to be defective or otherwise at fault.

Panela *v.* Castile Min. Co. (Michigan), 144 Northwestern, 528, p. 533, December, 1913.

INSUFFICIENT HOISTING APPARATUS.

The question of the negligence of a mine operator in using hoisting machinery for hoisting miners in a mine shaft, where it is necessary because of blasting being done in the shaft to hoist miners immediately upon a given signal, is one of fact to be determined by the jury in the trial of a case; but it is sufficient to entitle a case to go to the jury where the evidence shows that the puffer engine which operated the hoisting apparatus was a second-hand engine, was old, and that the company had been warned that it was out of repair and had in fact made some repairs, and that by reason of defects it would not operate quickly because of a bent shaft; that one of the valves was so slow that it required to be started slowly and that by reason of its defects the part connected with the shaft must be in a certain position or it could be started only with difficulty; and that at the time of the accident and consequent injury complained of there was a delay after the proper signal of three minutes before the engine started.

Panela *v.* Castile Min. Co. (Michigan), 144 Northwestern, 528, p. 534, December, 1913.

INSUFFICIENT SIGNALING SERVICE.

A mining company operated its mine and shaft by hoisting machinery located at a considerable distance from the mouth of the shaft and hoisted its elevator by means of a cable over a wheel or drum at an elevation of some 20 feet above the mouth of the pit. In elevating ore the elevator was hoisted to the crossbeam of the framework immediately below such wheel or drum, but in lifting the miners from the mine the elevator was halted at the ground level, and the signal for halting in either case was by wires attached to an angle iron on a pivot, one wire extending from such angle iron down the shaft and the other from such angle iron to a bell in the engine house near the hoisting engineer. Under such circumstances it is negligence for the mine operator to so adjust or permit the wire from such angle iron to the hoisting engine to be or become so slack that the proper signal whereby the elevator could be halted at the surface when lifting men from the mine could not be given, and the operator is liable for an injury to a miner where by reason of such slack and improper condition of the wire on the giving of the proper signal for halting the elevator at the surface level the hoisting engineer, because of the defective wire, received the signal for hoisting ore and carried the elevator to the crossbeam, thereby causing the injury complained of to a miner riding on the elevator.

Johansen *v.* Pioneer Min. Co. (Washington), 137 Pacific, 1019, p. 1022, January, 1914.

DEFECTIVE CABLE.

A mine operator is guilty of actionable negligence where he permits the wire rope drawing the cars on the tracks to become worn and defective, and where by reason of such worn and defective condition it broke, thereby causing a loaded car on one of the tracks to run with great and unrestrained speed down an incline and against the tipple building in which an employee was engaged in the performance of his duty as a weigher of coal, and with such force that it demolished the tipple and injured the weigher; and the operator in such case can not escape liability for permitting the use of the defective cable and for his negligent failure to furnish safe appliances and a safe place on the ground of the negligence of a fellow servant of the weigher in operating the particular car that caused the injury where the negligence of such fellow servant concurred with the operator's negligent use of the defective wire rope.

New Bell Jellico Coal Co. *v.* Oxendine (Kentucky), 160 Southwestern, 737, p. 742, November, 1913.

Burnet Fuel Co. *v.* Ellis (Texas Civil Appeals), 162 Southwestern, 911, p. 912, January, 1914.

A mine operator may be liable for the death of a miner caused by the breaking of the cable drawing a truck out of the mine on which the deceased miner and others were riding where the evidence shows that recently and prior to the accident the cable had parted and had been repaired and that there was a lack of proper inspection of the cable, and where a proper inspection might have disclosed the defects in the cable.

Dodd *v.* Summit Branch Min. Co. (Pennsylvania), 88 Atlantic, 927, p. 928, June, 1913.

KNOWLEDGE OF DEFECTS—DILIGENCE TO DISCOVER.

In an action against a mine operator for the death of a miner caused by the sudden starting of an engine due, as alleged, to the fact that the throttle valve had become worn and out of repair and leaked steam, a court can not say as a matter of law that prior inspection of the engine would have disclosed its defective condition in respect to the throttle valve, where such defect according to the proof was probably the result of long and gradual impairment by steam and hot water of the valve seat, nor can a court decide as a matter of law that sufficient time and opportunity were or were not afforded to the mine operator to discover, by proper inspection, the particular defect in the valve and to have remedied the same.

Espey *v.* Cahaba Coal Co. (Alabama), 64 Southern, 753, p. 756, February, 1914.

SIMPLE APPLIANCES.

While it is the duty of a mine operator to exercise ordinary care to furnish a miner reasonably safe appliances with which to work, yet there are some appliances so simple in their arrangement and make-up that a miner who voluntarily uses them must exercise at least ordinary care to protect himself from injury on account of any open and obvious defect in their condition; and when an experienced miner voluntarily and without any assurance of safety undertakes to work with a simple tool or contrivance he can not close his eyes to the obvious things immediately before him and say he did not see or know the conditions that existed; and this rule applies to the harness used on a mule drawing cars out of the mine where the fastening at the lower end of the hames came loose and thereupon the gear came off and the mule walked away from the car causing the miner to fall from the place he was sitting to the track, producing the injuries complained of.

Picker Gill *v.* Nelson Creek Coal Co. (Kentucky), 160 Southwestern, 936, p. 937, December, 1913.

A mine operator, as other employers, is only required to use ordinary care to furnish tools that are reasonably safe, and it is not his duty to furnish any particular kind of tools, implements, or appliances, but his duty in this respect is to use ordinary care and prudence in furnishing safe and suitable tools and implements, and no inference of negligence can arise from evidence which shows that an implement was such as is ordinarily used for like purposes by persons engaged in the same kind of business, and the fact that a mine operator furnished a bowlder hammer, the same kind of a hammer used throughout the mining district for similar work, and the mine operator can not be charged with negligence by mere proof that the hammer furnished was in such condition, by reason of its rounded head, that particles of rock would fly and scatter more than they would had a hammer been furnished that was but slightly convexed or which had a flat striking surface.

Sager *v.* Sampson Min. Co. (Missouri), 162 Southwestern, 762, p. 764, January, 1914.

A pick used by a miner is a tool of common use and of utmost simplicity, and where one is reasonably fit in the first instance for work in a mine the mine operator owes no duty of subsequent inspection.

Toth *v.* Osceola Consol. Min. Co. (Michigan), 146 Northwestern, 668, p. 669, April, 1914.

USING EXPLOSIVES.

UNSAFE EXPLOSIVES.

A mine operator negligently permitting the powder used in the mine to become wet, damp, and deteriorated is liable to a miner injured by reason of the condition of the powder, though the injured miner called the operator's attention to the condition of the powder but was assured by the operator that the powder was all right and safe, and on this assurance the miner had the right to rely unless he knew to the contrary.

Calausky *v.* Leigh Valley Coal Co., 212 Fed., 304, p. 307, March, 1914.

INJURY FROM UNEXPLODED BLAST.

A mine operator is liable for an injury caused to a miner by an unexploded blast, where the miner drilled into the walls of his chamber in the usual and approved manner and properly charged the hole, and the charge failing to explode, the miner thereupon and according to custom drilled another hole near the former, charged it with powder from another can and exploded the same, a method and custom followed in the mine, as the last explosion under ordinary circumstances and with suitable powder will explode the charge remaining in the first hole and remove all danger therefrom, and where by reason of the dampness of the powder used in the first charge the result of the negligence of the operator in storing the powder in a damp place the charge did not explode, and subsequently while handling the coal the charge was then exploded and injured the miner.

Calausky *v.* Leigh Valley Coal Co., 212 Fed., 304, p. 305, March, 1914.

USE OF DYNAMITE.

A miner does not assume the risks that are created by the negligence of the mine operator where the danger is not obvious and the place was not created by the miner in the performance of his work, but where the dangerous conditions were made by the explosion of dynamite in a deep and narrow trench or ditch in the mining of barytes the mine operator is liable for an injury to a miner caused by a large chunk of dirt or clay, broken loose by the explosions and rolling down upon the miner, causing the injuries complained of, as in such case it was the duty of the mine operator to exercise ordinary care to furnish the miner a reasonably safe place in which to work.

Evans Chemical Works *v.* Ball (Kentucky), 167 Southwestern, 390, p. 394, June, 1914.

Ohio Valley Coal & Min. Co. *v.* Heine (Kentucky), 167 Southwestern, 873, p. 874, June, 1914.

METHODS OF THAWING DYNAMITE.

In an action by a miner for injuries caused by an explosion of dynamite an allegation of negligence as to the method used for thawing the dynamite, in that electricity was used in such manner and to such a degree that portions of the explosives became heated to excess, is sufficiently sustained by proof that the dynamite when taken out for use by miners was so hot as to be sweaty and mushy and in that condition is especially dangerous to handle, the miners frequently feeling impelled to cool the overheated dynamite before using for fear of premature explosion; and where it also appeared that dynamite could be exploded by heat alone and where it was shown that on the day of explosion the dynamite had come from the thawer overheated.

West Lake *v.* Keating Gold Min. Co. (Montana), 136 Pacific, 38, p. 42, October, 1913.

FAILURE TO INSTRUCT.

INSTRUCTION UNNECESSARY.

It is a matter of common knowledge that when a rock is struck with a great force by an iron tool, such as a pick, whether sharp or dull, splinters are liable to fly as a result of the concussion, and a man 33 years of age who has spent his life in ordinary laborious occupations can not reasonably be supposed to be ignorant upon such a question and require instruction, and a mine operator in such case is under no duty to warn such a miner of the danger of splinters striking him in the eye.

Toth *v.* Osceola Consol. Min. Co. (Michigan), 146 Northwestern, 668, p. 669, April, 1914.
Picker Gill *v.* Nelson Creek Coal Co. (Kentucky), 160 Southwestern, 936, December, 1913.

INEXPERIENCED OR YOUTHFUL MINER.

While a master or a mine operator is not required to give warning of visible and obvious dangers to a miner possessing the intelligence, understanding, and experience sufficient to comprehend and appreciate them, yet it is equally well settled that if a miner is employed to perform work of a dangerous character or in a dangerous place, and is not experienced, and because of his youth or inexperience he may fail to appreciate the danger, it then becomes the duty of the master or mine operator before exposing the miner to such danger to give him such instructions or cautions as will enable him to comprehend them and do his work safely with proper care on his part.

Carney Coal Co. *v.* Benedict (Wyoming), 140 Pacific, 1013, p. 1015, May, 1914.

It is the duty of a mine operator to warn an inexperienced miner of the special hazards and dangers incident to his employment.

Looney *v.* Garfield Coal Co. (Iowa), 147 Northwestern, 129, p. 130, May, 1914.

to the miner an insurance of safety, and where the condition was not so dangerous or so obvious as to direct the miner's attention to it, or of such a nature as could be discovered by the exercise of ordinary care upon the miner's part.

Jellico Coal Min. Co. *v.* Helton (Kentucky), 163 Southwestern, 744, p. 745, February, 1914.

DUTY TO FURNISH SAFE PLACE.

A mine operator can not escape liability for injuries caused by falling rock, because of alleged negligence in failing to furnish a safe place, on the ground that the work that the miner was doing contributed to the falling of the rock, where the mine boss knew as well as the miner the kind of work he was going to do and how he was going to do it, and knew better than the miner whether the work he was doing would have a tendency to weaken the roof, thereby causing any loose rock or slate to fall, and where the mine boss knew that the roof in the particular vicinity was liable to fall, because of hill seams; and it was his duty before ordering the miner to work to take care commensurate with the probable danger to make the place safe, or to warn the miner that he must observe extra care on account of the dangerous condition prevailing.

Jellico Coal Min. Co. *v.* Helton (Kentucky), 163 Southwestern, 744, p. 746, February, 1914.

NEGLIGENCE OF FOREMAN—QUESTION OF FACT.

In an action by a miner for injuries caused by the alleged negligence of the mine foreman, where the evidence for the plaintiff shows that the foreman upon several different occasions had been negligent in his work and that his general reputation about the mine and where he had previously worked was that he was careless, and where the evidence on the part of the defendant showed that he was a careful and competent foreman, the question becomes one of fact to be determined by the jury trying the case.

Johansen *v.* Pioneer Min. Co. (Washington), 137 Pacific, 1019, p. 1021, January, 1914.

INCOMPETENT FOREMAN—PROOF OF REPUTATION.

In an action by a miner for personal injuries caused by the alleged negligence of the mine foreman or pit boss it is competent for the plaintiff to show specific acts of incompetency of the foreman or pit boss under a general allegation of ignorance and incompetency, and it is likewise competent to show, after proof of specific acts of carelessness, the general reputation of the foreman or pit boss for competency and regard for the lives and limbs of the miners under his charge, and such evidence is admissible to prove not only the unfitness of the foreman or pit boss but also to charge the operator with knowledge of such incompetency, where it is his imperative duty to know the fitness of his foreman.

Johansen *v.* Pioneer Min. Co. (Washington), 137 Pacific, 1019, p. 1021, January, 1914.

MINE FOREMAN—WHO IS.

A foreman is one who has immediate charge of a gang of workmen or miners and whose orders and authority in and about and concerning their work the workmen or miners are bound to obey, and a mine operator is under the duty toward his miners not to place incompetent or unfit persons in authority over them, and where a mine foreman for a long period of time has been in the employ of a mine operator the operator is charged with knowledge of foreman's general reputation in the community as to carelessness or incompetency.

Johansen *v.* Pioneer Min. Co. (Washington), 137 Pacific, 1019, p. 1022, January, 1914.

LIABILITY FOR NEGLIGENCE OF FELLOW-SERVANT.

STAGING MAN FELLOW-SERVANT OF MINERS.

Timbermen working on a timber staging in the shaft of a mine while the shaft and timbering are in process of construction are fellow-servants of the miner working in the shaft, where such staging was changed from day to day and the blasting left irregularities behind the timbers used in placing the sets, and the duty of carefully constructing such stagings and working on them was not a nondelegable duty, but one which the mine operator could delegate to the coemployees of the miner, and such coemployees are his fellow-servants for whose negligence the operator is not liable, as the doctrine of safe place does not apply while the shaft and timbering were in process of construction.

Kaaro *v.* Ahmeek Min. Co. (Michigan), 146 Northwestern, 149, p. 156, March, 1914.

FELLOW-SERVANT DOCTRINE OF LIABILITY.

The fellow-servant doctrine can not be interposed to defeat the liability of the operator of a coal mine for the death of a miner where the death was due to the failure of the operator to perform properly a nondelegable duty.

Big Hill Coal Co. *v.* Clutts, 208 Fed., 524, p. 526, November, 1913.

NEGLIGENCE OF FELLOW-SERVANT NOT A DEFENSE.

Under the Missouri statute (R. S. 1909, sec. 5440), providing that every person operating a mine producing lead, zinc, coal, or other minerals shall be liable for all damages sustained by the employees while engaged in operating such mine, by reason of the negligence of any other servant or employee, in the absence of contributory negligence the fellow-servant rule can not be interposed as a defense.

Martin *v.* Farmers' Coal Co. (Missouri), 160 Southwestern, 816, p. 818, November, 1913.

CARE IN SELECTING SERVANTS.

A mine operator is not responsible to a miner for injuries resulting from the negligence of a fellow miner engaged in a common employment where the operator has exercised due care in the selection and employment of such fellow miner; neither is the operator liable where a person employed to represent him in the general supervision of the mining operations departs from the scope of his employment and does the work of a fellow miner.

Maness *v.* Clinchfield Coal Corporation (Tennessee), 162 Southwestern, 1105, p. 1108, January, 1914.

NEGLIGENCE OF OPERATOR AND OF FELLOW-SERVANT.

Ordinarily a miner assumes the risks of injury by the negligence of a fellow miner but not the negligence of the fellow miner plus that of the mine operator, and the liability of the operator may exist though the negligence of the fellow miner was nearest the injury in point of time, if it was not the sole cause of the injury and if the injury would not have occurred but for the more remote negligence of the operator.

Humphreys *v.* Raleigh Coal & Coke Co. (West Virginia), 80 Southeastern 803, p. 806, February, 1914.

FELLOW-SERVANT'S DUTY TO KEEP APPLIANCES SAFE.

In an action against a mine operator for the death of a miner caused by the alleged negligence of the operator there can be no recovery under a count based on the common-law duty of the operator to furnish safe appliances and machinery, where the evidence shows that the duty of keeping such appliances and machinery in proper condition was committed to the fellow-servants of the intestate and that the particular defect complained of was due to want of care and diligence in inspecting and in repairing the defective condition on the part of such fellow-servants.

Espey *v* Cahaba Coal Co. (Alabama), 64 Southern, 753, p. 754, February, 1914.

WHO ARE FELLOW-SERVANTS.

An employee of a smelting and refining company employed and working for a smelting works and who was directed to sweep off the tramway tracks is a fellow-servant with the motorman running a motor engine whose duties were to operate the cars and motor, being small ore cars and a motor used to haul ores from the roaster up to the reverberatories, and the smelting corporation is not liable an injury to such sweeper caused by the negligence of the man operating the motor.

Consolidated Kansas City Smelting & Refining Co. *v.* Lopez (Texas Civil Appeals), 166 Southwestern, 498, May, 1914.

NEGLIGENCE OF FELLOW-SERVANT AND OF INJURED MINER.

A mine operator is not liable for the death of a miner where either he or a coal miner in an adjacent entry, or both, drove their headings unduly wide, thereby leaving the wall or rib so thin that a blast in the adjacent entry or heading burst through the thin wall, causing his death, as this did not constitute an unsafe place within the common-law doctrine of the operator's duty in respect to furnishing his miner a safe place in which to work, for the reason that the work in which the deceased miner and his cominer were engaged created the place itself and the defective condition complained of.

Sloss-Sheffield Steel & Iron Co. *v.* White (Alabama), 65 Southern, 999, p. 1,000, May, 1914.

MINER'S WORKING PLACE.

WHAT CONSTITUTES—QUESTION OF FACT.

Where it is a miner's duty to make and keep his working place safe, and where it is the operator's duty to keep other places and entries in the mine safe, and where in an action for damages for the death of a miner caused by a fall of rock from the roof, and where there is a conflict of evidence as to whether the miner was killed in his working place and at a point where the mine operator would be liable, the question of what constitutes the miner's working place and whether the death occurred at such place becomes one of fact to be determined by the jury trying the case.

Goode *v.* Central Coal & Coke Co. (Missouri Appeals), 166 Southwestern, 844, May, 1914.

In an action to recover damages for the death of a miner caused by the falling of a large rock from the roof, due to the alleged negligence of the mine operator, under an allegation that the miner was killed while eating his lunch "at a point in the mine from 15 to 25 feet north of his working place," the plaintiff is not compelled literally to sustain the allegation in the petition that the miner was killed between 15 and 25 feet from his working place, as the substantial point of controversy was whether the miner was killed away from his working place, where the operator would be liable for the condition of the roof, or at his working place, where he was supposed to look out for himself, and the operator would not be liable; and if he was not at his working place when killed it is of no consequence whether he was at a less or a greater distance from his working place, and the distance is not material unless the exact distance affected the operator's liability on the main charge, and then it would be proper to require strict proof of the allegation.

Goode *v.* Central Coal & Coke Co. (Missouri Appeals), 166, Southwestern, 844, May, 1914.

MINER EATING LUNCH—WORKING PLACE.

A miner directed by the mine foreman to leave his regular work and working place to perform services in other parts of the mine and in a place that is in fact dangerous, and of which he has no knowledge, is within the scope of his employment where at the proper hour he was eating his lunch within a few feet of his working place and during that time received the injuries complained of, and he had not thereby voluntarily left his working place and was not outside of the scope of his employment.

Domestic Block Coal Co. *v.* Holden (Indiana Appeals), 103 Northeastern, 73, p. 77, November, 1913.

FAILURE TO MAKE WORKING PLACE SAFE.

A mine operator engaged in mining barytes by means of an open ditch some 25 feet wide at the top, 12 feet at the bottom, and of a depth varying from 15 to 25 feet, is guilty of actionable negligence in failing to exercise ordinary care to make the working place safe and by reason of the mine foreman negligently ordering the miner to work in such unsafe place where without any warning and without any knowledge on his part of the danger and by reason of the steep sides of the mining ditch a large lump of dirt and clay, loosened by reason of explosives used, rolled down the bank and caused the injuries complained of.

Evans Chemical Works *v.* Ball (Kentucky), 167, Southwestern, 390, p. 391, June, 1914.

MINER MAKING PLACE SAFE.

The general duty of a master of an employer to provide safe working places for his employee does not apply where the employee either by custom or contract is engaged in making his own place safe and where the character of the work is such that the condition of the place as represents safety necessarily changes as the work progresses and by reason of the work itself, as it is impracticable, if not impossible, for the employer to look out and provide for the safety of the employee under such circumstances; and this exception has special application to the work in a mine of cutting down and blasting coal, as in such case the character of the place is constantly changing and the miner is in fact making his own working place; but when the place where the work is being done ceases to be one which the miner makes for himself as an incident to his work, and the work being done does not necessarily change the character of the place as respects safety within the obligation of reasonable care, then the duty to keep such places safe rests primarily upon the mine operator.

Dasher *v.* Hocking Min. Co., 212 Fed., 628, p. 632, April, 1914.

CONTRIBUTORY NEGLIGENCE OF MINER.

RECOVERY NOTWITHSTANDING CONTRIBUTORY NEGLIGENCE.

A miner may recover for an injury caused by the negligence of a mine operator, though his own negligence contributed to the injury, if the operator might by the exercise of reasonable care and prudence and by giving timely warning have avoided the consequence of the miner's negligence.

Big Hill Coal Co. *v.* Clutts, 208 Fed., 524, p. 526, November, 1913.

BURDEN OF PROOF.

In the Federal courts the burden is upon the defendant mine operator to show that the injury to a miner sustained while obeying the orders of his superior was the result of his contributory negligence or that his negligence contributed to the injury.

Philadelphia & Reading Coal, etc., Co. *v.* Keslusky, 209 Fed., 197, p. 199, November, 1913.

In an action against a mining company for the death of an employee where the cause of the death is not explicable and where nothing is shown as to the conduct of the deceased immediately prior and at the time of receiving his death by an electrical current, the burden of proving contributory negligence on the part of the deceased sufficient to relieve it from liability is on the defendant and is a question of fact for the jury unless there is but one conclusion which can reasonably be reached from the evidence.

Hill *v.* Pacific Gas & Electric Co. (California), 136 Pacific, 492, p. 499, November, 1913.

FAILURE TO COMPLY WITH RULES.

Where a rule of a mine provided that no employee should come into the shaft where timbering was going on without knocking on the pipe, and should not attempt to ascend without answer by the timberman by rapping on the pipe and calling down, and a machinist who failed to observe the rule and was killed at the bottom of a shaft by falling timber is guilty of such contributory negligence in failing to comply with the rule as will defeat a recovery.

American Zinc Co. *v.* Smith (Missouri), 161 Southwestern, 494, p. 495, November, 1913.

VIOLATION OF RULE OF MINE.

An experienced miner who was injured by a fall of slate from the roof of a mine can not recover for an injury where the evidence shows that at the time the slate fell, and as a cause of its falling, the miner was digging down coal from an entry stump contrary to the rules of the mine, known to him, and while so digging down coal from the entry stump other miners warned him that the slate was loose and liable to fall.

Sams *v.* Grey (Kentucky), 161 Southwestern, 553, December, 1913.

DELEGATION OF DUTY—GIVING OF SIGNALS.

While under certain circumstances the giving of signals may be a nondelegable duty of the master, yet it is not meant by the word "nondelegable" that the master may not impose the duty upon a given employee to give signals prescribed for his own safety; and an action can not be maintained by an injured miner where it was his duty to direct other employees by means of signals, and where his own injury was due to the fact that such signals were improperly given, or were not given at such time and place as his duty required.

American Zinc Co. *v.* Smith (Missouri), 161 Southwestern, 494, p. 495, November, 1913.

QUESTION OF FACT.

The question of the contributory negligence of a miner is a question of fact to be submitted to a jury in an action by the miner for personal injuries unless the evidence is without conflict and is of such character as to afford no opportunity for fair-minded men to differ upon the conclusion to be reached thereon, and in such case it may become a question of law for the court.

Carney Coal Co. *v.* Benedict (Wyoming), 140 Pacific, 1013, p. 1015, May, 1914.

ADMISSIBILITY OF STATEMENTS OF INJURED MINER.

A voluntary declaration or statement made by an injured miner to a third person after he received the injury and after he had begun an action to recover damages, as to his knowledge of the cause of the injury and as to his negligence contributing to bring it about, is admissible in evidence as a declaration against his interest, and especially so if such statement or admission is contrary to the position taken by the party at the trial of the case.

Peterson *v.* Pittsburg Silver Peak Gold Min. Co. (Nevada), 140 Pacific, 519, p. 525, April, 1914.

KNOWLEDGE OF DANGER.

In an action by a miner for injuries occasioned by the falling of rock and slate from the roof of an entry the plaintiff can not recover if he was guilty of negligence which proximately contributed to cause his injuries, and if he had knowledge of the particular danger which caused the injury and of the alleged defect in the defendant's ways, works, machinery, and with such knowledge went in close and dangerous proximity to such dangers and defects, knowing at the time that he would likely or probably be injured, and was in fact injured as a proximate consequence of such negligence.

Doss *v.* Wadsworth Red Ash Coal Co. (Alabama), 64 Southern, 341, p. 342, January, 1914.

KNOWLEDGE OF DANGER—MINER CREATING DANGEROUS CONDITION.

An experienced miner engaged at the direction of the pit boss in brushing the roof of an entry to make it of sufficient height to admit cars can not recover for the injuries caused by the fall of slate from the roof where he is working, though directed by the pit boss to proceed with the brushing until completed before timbering, where he knew how to test the condition of the roof by sounding, and where sounding would have revealed to him the danger; and in an action for damages under such circumstances the burden of proof was on him affirmatively to prove his freedom from contributory negligence.

Williams *v.* Craig Dawson Coal Co. (Iowa), 146 Northwestern, 735, p. 736, April, 1914.

INJURY TO MINER—PROOF OF CUSTOM.

In an action by a miner for injury caused while riding on a skip being drawn out of the mine it is proper to show, as against a charge of contributory negligence and a violation of rules in that not more than five persons should ride on a skip and that no miner should sit on the bail of the skip, a position regarded more dangerous, that it was customary for six miners to ride out of the mine in the skip at one time, and that when six persons were riding in the skip it was necessary that one of them should sit upon the bail.

Federal Min. & Smelting Co. *v.* Hodge, 213 Fed., 605, p. 607, May, 1914.

CAPACITY OF EMPLOYEE PRESUMED.

In an action by a miner for injuries against a mine operator the operator may, as against a charge of negligence, presume that an employee was a person of normal capacity for understanding and appreciating dangers, that he was in good health, and his general faculties as to memory and otherwise were excellent; but this presumption is only the equivalent of the statement that the question whether the employee ought to have known of the defective conditions surrounding him must be considered in the light of his capacity for understanding the dangers of his position, and an instruction to that effect is not erroneous.

Ingalls *v.* Monte Cristo Oil & Development Co. (California), 139 Pacific, 97, p. 99, March, 1914.

FAILURE TO HEED WARNING.

A miner is guilty of contributory negligence in attempting to pass through an open cage at the bottom of the shaft and not heeding a timely warning that the signal had been given and the cage would be started; and it is immaterial under such circumstances whether the warning was given by the mine foreman or by a coemployee if the warning was timely and sufficient to advise the miner of the danger in attempting to enter the cage.

Kentucky Midland Coal Co. *v.* Vincent (Kentucky), 166 Southwestern, 815, May, 1914.

EMPLOYEE PURSUING DANGEROUS METHOD.

An employee injured while pursuing a dangerous method of ascending a ladder on an oil derrick is guilty of contributory negligence where an ordinarily prudent person would have pursued a safer method for such purpose.

Guffey Petroleum Co. *v.* Dinwiddie (Texas Civil Appeals), 168 Southwestern, 439, p. 443, June, 1914.

In an action for the death of a miner due to the alleged negligence of the operator in that the miners working for the operator negligently caused a car to run against him, thereby killing him, a plea of contributory negligence is sufficient where it avers that the car was being drawn along the track by a cable attached to a drum near the opening of the mine, which the deceased miner knew; that the track was on a slope leading out of the mine; that the slope at the place where the deceased miner was struck by the car was unobstructed for a distance of 5 feet on either side of the track, and that the deceased miner, being aware that the car was approaching and was in dangerous proximity to him, negligently failed to get off the track before the car struck him.

Haigler *v.* Sloss-Sheffield Steel & Iron Co. (Alabama), 65 Southern, 801, p. 802, June, 1914.

There can be no recovery for the death of a miner under the Alabama statute on the alleged ground of negligence in the operator for a defect in the condition of the ways, works, machinery, or mine of the operator which had not been discovered or remedied where the defective condition was brought about either by the disobedient or negligent execution of the work of the deceased miner, or where his death occurred contemporaneously with and in the course of his creation of the particular condition.

Sloss-Sheffield Steel & Iron Co. *v.* White (Alabama), 65 Southern, 999, p. 1,000, May, 1914.

FREEDOM FROM CONTRIBUTORY NEGLIGENCE.

MINER MAY ASSUME PLACE IS SAFE.

Where a miner is ordered by a mine operator to leave his accustomed place and work, and engage in other work for the operator which subjects him to increased or additional danger, unknown to him, he has a right to assume that the operator has used ordinary and reasonable care to make the particular place where he is required to perform the new and temporary service reasonably safe and that the operator will, at least, use ordinary care to keep the place safe while he is doing the work.

Domestic Block Coal Co. *v.* Holden (Indiana Appeals), 103 Northeastern, 73, p. 75, November, 1913.

MINER MAY RELY ON OPERATOR PERFORMING DUTY.

A miner working in a mine as a driller, and whose only duty it was to drill after the place had been prepared for him and who was under no obligation to test or make inspection of the entry or place in which he is sent to work, has a right to rely upon an inspection made by the ground boss and shovelers whose duty it was to inspect and make such places safe, unless the danger was open and obvious, and under such circumstances he is entitled to recover for an injury received by falling rock, and especially where the evidence shows that while the injured miner was working in another part of the mine the foreman discovered that the place in question was dangerous and sent the driller there to work without warning him of the danger.

Dolphin *v.* Peacock Min. Co. (Wisconsin), 144 Northwestern, 1112, p. 1114, January, 1914.

ANSWER OF CONTRIBUTORY NEGLIGENCE INSUFFICIENT.

In an action for damages for injuries received in a mine the plaintiff alleged in his complaint that it was his business to drive cars loaded with coal drawn by mules along an air course in the defendant's mine leading to an entry therein, and that in performing such work he was required to pass a trapdoor, and that the superintendent in the mine while acting as such negligently caused cars to be placed in the air course between the entry and the trapdoor without the plaintiff's knowledge, and while driving along the air course, and without seeing the cars or knowing of their presence, plaintiff drove his mule up against the car so placed and thereby caused the injury complained of, and an answer by the mine operator to the effect that the plaintiff was guilty of negligence which proximately caused his injury, in that it was his duty to keep a lookout along the track in front of him to discover and avoid injuries from obstructions therein, and that he negligently failed to keep such lookout and thereby failed to discover the obstruction in time to avoid injury, and thereby proximately caused the injury, is defective for failing to aver that the obstruction could have been discovered or that the injury could have been avoided by keeping a lookout.

Sloss-Sheffield Steel & Iron Co. *v.* Russell (Alabama), 65 Southern, 137, April, 1914.

KNOWLEDGE OF DANGER—ASSURANCE OF SAFETY.

A miner under 20 years of age who had had but little experience as a coal miner and had no previous experience in the particular mine can not be charged, as a matter of law, with contributory negligence for working in a dangerous place where it appears that the mine foreman assured him that the place where he was put to work was safe and where he examined and tested the slate and there was nothing in its appearance to indicate that it would fall and where the danger from draw slate was not so obvious that a person of ordinary prudence would have refused to go on with the work.

Interstate Coal Co. *v.* Trivett (Kentucky), 160 Southwestern, 728, p. 730, November, 1913.

WANT OF KNOWLEDGE OF DANGER—RIDING ON TOP OF ELEVATOR.

A miner is not to be charged with contributory negligence where in being hoisted from the mine he was directed by the foreman to take a position on the top of the cage, there being insufficient room for all the miners in the cage, and where the foreman in the cage gave the proper signal for hoisting the cage and for stopping it at the surface level, pursuant to the regular signal code, but where by reason of the operator's negligent and improper method of maintaining the signal wire and appliance the proper signal for stopping the cage at the surface level was not received by the hoisting engineer, but by reason of such negligent and improper method of maintaining the signal wire and appliance the hoisting engineer received a different signal indicating that the cage was to be carried to the top of the framework supporting the elevator drum or wheel, to which point the cage was carried in dumping ore, and where by reason of such defective signaling system the miner received the injuries complained of, and where the injured miner did not know that the position in itself was dangerous, and where it did not appear to be dangerous, and where he did not know of the defective signaling system, and where it appeared that miners did frequently take a position on the top of the cage in riding out of the shaft.

Johansen *v.* Pioneer Min. Co. (Washington), 137 Pacific, 1019, p. 1022, January, 1914. See Federal Min. & Smelting Co. *v.* Hodge, 213 Fed., 605, p. 607.

OBEDIENCE TO FOREMAN'S ORDERS—RIDING ON TOP OF CAGE.

A miner injured while riding on the top of the cage in being carried out of a mine is not to be charged with contributory negligence where he took his position on the top of the cage in obedience to the orders of the mine foreman, and where the danger was not so glaring and apparent that a reasonably prudent person would have refused to obey the order given and where miners frequently rode out of the mine on the top of the cage, and a miner under such circumstances is required to obey and is still under the direction of the foreman in going to or from his work as much as while actually engaged in the work itself.

Johansen *v.* Pioneer Min. Co. (Washington), 137 Pacific, 1019, p. 1023, January, 1914.

FAILURE TO HEED WARNING.

A miner killed in the haulageway or tunnel of a mine by cars of loaded coal is not to be charged with contributory negligence because he did not heed the suggestion of a trapper boy and wait for the trip of cars out of the mine, where it appeared that the trapper boy had no knowledge as to when the driver would be out or how long it would be necessary to wait, as the cars ran at irregular periods, and where to attribute contributory negligence to the deceased miner for failing to wait for the trip out would necessarily imply that the haulageway or tunnel beyond the trapdoor was inherently dangerous as it was then being operated.

National Fuel Co. *v.* Maccia (Colorado), 139 Pacific, 22, p. 24, March, 1914.

PERFORMANCE OF UNUSUAL DUTIES.

A motorman operating a motor in a coal mine injured by projecting timbers from another motor or coal car standing on the track, and of which he had no knowledge, can not be charged with contributory negligence for failing to observe the cars and the projecting timber and avoiding the danger where it appeared that the trolley line at and near the point where the cars were standing had for sufficient reasons been elevated and that it was necessary for the motorman at and near this point to hold the trolley on his motor up against the trolley wire, and in addition to the ordinary conditions existing at this place a kink in the trolley wire made it necessary for him to give attention to keeping the trolley pole in contact with the trolley wire instead of looking ahead of his motor, and especially in view of the fact that he had a right to rely upon the premises being kept reasonably safe for him to do the work that his foreman had directed him to do.

Stonega Coke & Coal Co. *v.* Williams (Virginia), 80 Southeastern, 100, p. 102, November, 1913.

OBEYING INSTRUCTIONS OF PIT BOSS.

A coal miner engaged in brushing an entry under the directions of the pit boss has the right to assume that work may be done safely in the manner directed by such pit boss, unless obviously dangerous, or as an ordinarily prudent man he must have known better and whether acting as an ordinarily cautious person would in a like situation, he ought to have proceeded with the work as directed.

Williams *v.* Craig Dawson Coal Co. (Iowa), 146 Northwestern, 735, p. 736, April, 1914.

INEXPERIENCED MINER.

An inexperienced miner put to work in a part of a mine where it was not his duty to inspect the roof and who did not know of the dangerous condition of the roof, or the hazards incident to work thereunder, can not be charged with contributory negligence in case of injury, nor does he under such circumstances assume the risk of such danger.

Looney *v.* Garfield Coal Co. (Iowa), 147 Northwestern, 129, p. 131, May, 1914.

QUESTION OF FACT.

A car driver in a drift mine injured by a collision with an empty car can not as a matter of law be charged with contributory negligence where after he had left a train of empty cars at a suitable place he then hitched to the train of loaded cars and started them out of the mine, and where in the meantime the driver of another train of empty cars had so dumped his cars that one of them obstructed the track, and where the lights in the trackway were so dim that the driver in passing out with the loaded train could not see that one of the empty cars protruded from the track on which he was passing.

Martin *v.* Farmers' Coal Co. (Missouri), 160 Southwestern, 816, p. 818, November, 1913.

RIDING ON BAIL OF SKIP.

It is not contributory negligence as a matter of law for a miner to sit on the bail of a skip while being drawn out of the mine at an angle of about 45° and where it was customary for a miner to so ride when the skip was crowded with men, and a miner occupying such position and injured by coming in contact with the bulkhead is not, as a matter of law, prevented from recovering where the injury could have been avoided by the use of the statutory indicator or a competent signaling device.

Federal Min. & Smelting Co. *v.* Hodge, 213, Fed., 605, p. 608, May, 1914.

PRESUMPTION AS TO PERFORMANCE OF DUTY.

Where the obligation on the part of an employer to exercise reasonable care to furnish a reasonably safe place exists, the employee may properly act upon the presumption that the duty has been performed, and he is not guilty of contributory negligence in so doing unless he knows, or by the exercise of reasonable care or prudence should have known, of the defect and danger complained of.

Dasher *v.* Hocking Min. Co., 212 Fed., 628, p. 629, April, 1914.

INSTINCTS OF SELF-PRESERVATION—PRESUMPTION.

Where an accident occurred in a mine resulting in the death of a miner by being caught and crushed between a car and the ribs of a tunnel, and where there was no witness to the accident, the presumption will be indulged that the deceased was in the exercise of ordinary care under the circumstances at the time of the accident.

Smith *v.* Stoner (Pennsylvania), 89 Atlantic, 795, p. 797, January, 1914.

Where a miner was injured by a fall of over 50 feet from a ladder, due to the negligence of the operator, and the injuries to the employee were such that the incidents of the accident are a blank to him and he is unable to give any account of his acts or doings at the particular time of the accident, it will be presumed that he was exercising due care at the time, unless the circumstances point to the contrary; but if the injured employee was pursuing a dangerous method of ascending the ladder, and if an ordinarily prudent man would have pursued a safer method for that purpose, then the presumption of the exercise of due care can not prevail.

Guffey Petroleum Co. *v.* Dinwiddie (Texas Civil Appeals), 168 Southwestern, 439, p. 443, June, 1914.

A miner injured by a fall of rock from the roof of a room neck is not, as a matter of law, to be charged with contributory negligence, because he admitted that he knew that the roof was bad and had notified the mine foreman of the condition and requested him to make it safe, where the situation was not such as to show that it was obvious to the miner that the roof threatened immediate danger; and he had a right to continue using the passageway, provided a reasonably prudent man in his situation would have concluded that he could do so without subjecting himself to the danger of immediate injury.

Gambino *v.* Manufacturers' Coal & Coke Co. (Missouri Appeals), 164 Southwestern, 264, p. 266, February, 1914.

PROOF OF CUSTOM.

In an action by a miner injured while riding on a skip being drawn up in a shaft, and where it appeared that the miner was sitting on the bail and cable, it is proper to prove that it was customary for miners to ride where the injured miner was riding, for the purpose of showing the customary method of using the skip and for the light which it might incidently afford on the question of the miner's contributory negligence, and the mere fact that other miners may have ridden in the same position is not conclusive of the question of the negligence or want of negligence on the part of the injured miner, nor does it expressly show the assent of the mining company to any particular manner or method of using the skip.

Federal Min. & Smelting Co. *v.* Hodge, 213 Fed., 605, p. 607, May, 1914.

CONTRIBUTORY NEGLIGENCE OF MINER EXCUSED.

An action for the death of a miner can not be defeated by the mine operator by showing that after the miner made the proper request for props and after the operator failed to furnish the props on the miner's demand, by showing that the miner was guilty of contributory negligence in continuing to work in the place he regarded dangerous and that there were other places in which he could have worked safely, where it is not made to appear that the danger of working in the place in which the miner lost his life was not so apparent and impending that an ordinarily prudent person would have rejected the risk.

Continental Coal Corporation *v.* York (Kentucky), 167 Southwestern, 131, p. 132, June, 1914.

ASSUMPTION OF RISK.

Risks Assumed.
Risks Not Assumed.

RISKS ASSUMED.

BURDEN OF PROOF.

Where a miner shows that he was injured in consequence of an unusual risk, due to the operator's negligence, the operator then has the burden of proof of showing that the miner knew of the unusual dangers; but the rule only becomes applicable in a case where the servant is injured on account of some risk unusual and unknown, and he is entitled to recover if he establishes either proposition.

Oiva *v.* Calumet & Hecla Min. Co. (Michigan), 146, Northwestern, 181, p. 185, March, 1914.

QUESTION OF FACT.

Whether or not a miner assumed the risk of injury is a question of fact for the jury in an action by the miner for personal injuries, and a court is not authorized to say, as a matter of law, that the danger was obvious, unless it is shown by the evidence without conflict that an ordinarily prudent man or one with the experience of the injured miner ought to have known the danger.

Carney Coal Co. *v.* Benedict (Wyoming), 140 Pacific, 1013, p. 1015, May, 1914.

DISTINCTION BETWEEN ASSUMPTION OF RISK AND NEGLIGENCE.

There is a wide distinction between assumption of risk and negligence; and while in assuming a risk where danger is so imminent as to make such assumption a rash act an employee may be guilty of negligence, and while upon the other hand an employee who has not assumed a risk may yet suffer an injury for which he can not recover damage owing to the negligence on his part contributing to the injury, but ordinarily mere assumption of risk is not in itself negligence.

Perreault *v.* Wisconsin Granite Co. (South Dakota), 144 Northwestern, 110, p. 113, September, 1913.

KNOWLEDGE OF DANGER.

If a miner has knowledge of a defect in the roof of his entry or working place, or if such defect was so obvious to him that he could not but have known it, he is to be charged with the assumption of the risk if he continues to work with knowledge of such danger.

Victor-American Fuel Co. *v.* Peccarich, 209 Fed., 568, p. 571, November, 1913.

It is the duty of a mine operator by its foreman or mine boss to use ordinary care to timber the roof of a mine, and the failure to exercise such care will render the mine operator liable in case of injury to a miner; but if the miner by the work he does makes the place dangerous and he knows the danger, or by ordinary care in the discharge of his duties should have known it, and with this knowledge continues the work, he assumes the risk and the operator is not liable for a resulting injury.

Cooke-Jellico Coal Co. *v.* Richardson (Kentucky), 161 Southwestern, 537, p. 540, December, 1913.

A miner injured by slate falling from the roof at a point where he was working, assumes the risk of danger where he has knowledge of the dangerous condition of the roof and knew that props were necessary to the safety of the place and where props had been furnished by the operator for the purpose of propping the roof but were not used because they would make it more inconvenient for the miner to get the coal from the place where he was digging to the cars.

Branson *v.* Clover Fork Coal Co. (Kentucky), 164 Southwestern, 304, p. 305, March, 1914.

An employee in a stone quarry assumes the risk of injury from dangers of which he has knowledge, and the rule applies to dangers which he might have discovered by the exercise of reasonable care, and especially where the danger is of such a character that any person of ordinary intelligence could understand and appreciate; and in cases to which the doctrine of assumption of risk applies it must be held, as a matter of law, that an employee who voluntarily encounters a known and appreciated danger assumes the risks of any injury resulting therefrom.

Sare *v.* Hoadley Stone Co. (Indiana Appeals), 105 Northeastern, 582, p. 584, June, 1914.

SAFE PLACES—MINER MAKING PLACE SAFE.

A mine operator is not liable for the death of a trammer on the ground of alleged negligence in failing to furnish a safe working place where it appears that trammers and miners were working together in a stope and it was the duty of the miners to inspect the wall, and had in fact inspected and taken down loose rock from the hanging wall of the stope recently before the accident, and the operator can not be charged with negligence in failing to furnish a safe working place where inspection was properly and carefully made by the proper persons and especially where the trammers and miners jointly acting together were making the place of work, in part at least.

Kochin *v.* Superior Copper Co. (Michigan), 148 Northwestern, 252, p. 253, July, 1914.

DIFFERENT METHODS OF PERFORMING SERVICE.

Where there are two methods by which a service may be performed one perilous and the other safe, a miner who voluntarily chooses the perilous rather than the safe one assumes the risk of such perilous one; but the rule does not apply where it is not shown that the miner knew that the method he adopted was a dangerous one, or that it was in fact more perilous than the other, in the absence of the operator's negligence; and if a danger is not so absolute or imminent that injury must almost necessarily result from an obedience on the part of the miner to an order, and the servant obeys the order and is injured, the operator can not defend himself on the ground that the miner should not have obeyed the order.

Johansen *v.* Pioneer Min. Co. (Washington), 137 Pacific, 1019, p. 1022, Januray, 1914.

KNOWLEDGE OF SAFE AND DANGEROUS METHODS.

A miner engaged in a coal mine assumes the risk of the dangerous condition of a roof in an entry, notwithstanding the negligence of the mine operator in permitting the roof of the entry to remain in a dangerous condition, where with knowledge of such danger the miner voluntarily uses the entry, when there is a safe entry equally convenient and known to him, on the theory that where there is open to a servant or miner the selection of a safe and an unsafe way of using implements or premises, and with knowledge of the conditions he voluntarily and knowingly selects the unsafe way, he takes the risk of any accident that may happen to him.

Elliott *v.* Greenville Coal Co., 167 Southwestern, 424, p. 425, June, 1914.

MINER MAKING HIS OWN WORKING PLACE.

The duty of a mine operator to furnish a reasonably safe place to work and to use ordinary care to keep safe, or as to directing and permitting work in an unsafe place, is a qualified duty and does not extend to all the passing risks that may arise in ever changing conditions of the safety of the work in the ordinary and usual conditions of the work of which the miner is as well informed as the mine operator, or the danger is open and obvious, or can be discovered by the use of ordinary care, or under circumstances which impose on the miner the duty of making safe, or where he is engaged in making safe the place where he works.

Lehigh Portland Cement Co. *v.* Bass (Indiana), 103 Northeastern, 483, p. 486, December, 1913.

ASSUMPTION OF RISK.

A miner employed to look after the safety of the room, chamber, or entry, and whose duty it is to make dangerous places therein safe, assumes the risk incident to such work and the mine operator is not liable for resulting injury.

Big Hill Coal Co. *v.* Clutts, 208 Fed., 524, p. 529, November, 1913.

Where a danger is obvious to a miner he assumes the risk and the employer will not be liable for injuries that may happen to him; and generally a miner assumes the ordinary risks of the employment, and where the miner creates the danger in the progress of his work he must take care to protect himself.

Evans Chemical Co. *v.* Ball (Kentucky); 167 Southwestern, 390, p. 393, June, 1914.

MINER INJURED BY FALLING TIMBER.

A miner whose duty was to load material from the mills at the foot of the stopes in a mine into a tramcar and push the car to a hoist assumes risks directly connected with his work, among them the risk that, notwithstanding skillful inspection of the walls at proper intervals, material may become dislodged from the wall of a mine and go down a stope into the mills at the foot of the stope.

Oiva *v.* Calumet & Hecla Min. Co. (Michigan), 146 Northwestern, 181, March, 1914.

UNEXPLODED BLASTS—LIABILITY.

Where the evidence shows that four experienced miners were employed by a mine operator in sinking a winze, and two worked on the day and two on the night shift and did the drilling, blasting, and cleaning out of the winze as they proceeded, and after some days the miners on the day shift had drilled in the rock seven holes filled with explosives from 5 to 6 feet in length, one of which was in the center of the circle made by the other six, and in making the explosion and while one cap and one fuse were used to each drill hole, the charges were so close to each other that in fact one explosion was all that sometimes could be heard, two or more at other times, and the fact that a less number than seven explosions could be counted was no evidence that any charge remained unexploded, all of which was known to the miners, and usually the results of the blast were left in the pit to be cleaned out by the succeeding shift and these took conditions as they found them with such warning as the outgoing shift might leave, and the miners under the circumstances are the men upon whom rests the duties to do all that is required to be done, under such circumstances and under the manner in which the work was necessarily performed the mine operator can not be charged with negligence in failing to notify the miners of an oncoming shift that there remained unexploded blasts or that the preceding shift who shot off the blasts did not hear as many explosions as there were blast holes; but in such case the miner assumes the risk of the injury from unexploded blasts.

Conradsen *v.* Osceola Consol. Min. Co. (Michigan), 146 Northwestern, 638, p. 642, April, 1914.

CONSTRUCTION OF ENTRY IN COAL MINE.

Ordinarily a miner in making or completing an entry in a coal mine takes the risk of the dangers which develop as the work progresses, for he makes his own working place.

Williams *v.* Craig Dawson Coal Co. (Iowa), 146 Northwestern, 735, p. 736, April, 1914.

DRIVER OPERATING SWITCHES.

A driver employed to haul coal cars out of a mine and whose duty it was among other things to operate and adjust the switches along the tracks by means of levers, assumes the danger necessarily incident to such work and can not recover for an injury where in attempting to reach a switch while standing inside of an empty car he reached out in an effort to throw the switch and lost his balance and fell thereby causing the injury, though he had been directed to throw the switches while the cars were in motion, yet he had the right to stop and throw the switch if he desired.

Wallace *v.* Columbia Coal Co. (Kentucky), 166 Southwestern, 769, May, 1914.

RISKS NOT ASSUMED.

MAKING DANGEROUS PLACES SAFE.

A miner contracted to build a wall across a certain entry to keep out fire damp coming through such entry from an old mine must be regarded as in the line of his duty where he left the work of building the wall and went some distance to replace a curtain or blanket to keep out the fire damp from the old mine and supply his working place with fresh air and which had been displaced by blasting carried on by other miners at the direction of the mine operator and which blasting weakened the roof of the entry through which the miner was required to pass and by reason of which he was injured.

Victor-American Fuel Co. *v.* Peccarich, 209 Fed., 568, p. 572, November, 1913.

A motorman operating a motor hauling coal cars in and out of a mine does not assume the risk of dangers due to the negligence of the operator and does not assume the dangers incident to projecting timbers on cars on an adjoining track where, by reason of the condition of the trolley line and acting under the direction of the foreman, his attention was taken from the operation of the motor by being required to hold the trolley pole against the wire at the time he received the injuries for which he sues.

Stonega Coke & Coal Co. *v.* Williams (Virginia), 80 Southeastern, 100, p. 108, November, 1913.

A mine operator must take reasonable care to protect his miners from injury and he owes them the duty of providing them with a reasonably safe place in which to work and of maintaining it in a reasonably safe condition during the employment, having regard to the character of service required and the dangers that a reasonably prudent man would apprehend under the circumstances of each particular case; and this positive duty which the mine operator owes is not one of the perils or risks assumed by the miner in the contract of employment, and the miner is entitled to rely upon the assumption that the mine owner has performed the duty imposed on him by law.

Big Jack Min. Co. *v.* Parkinson (Oklahoma), 137 Pacific, 678, p. 681, December, 1913.

A miner injured while riding out of the mine on the top of a cage, having been directed to take such position by the mine foreman where the cage was filled with other miners, is not to be charged with assumption of the risk, because of the presence of a ladder up the shaft and by which he could climb out of the shaft with perfect safety, where his alleged injury was caused by the negligence of the mine operator and where it was customary for miners to ride out of the mine on top of the cage and the position was not in itself dangerous in the absence of the operator's negligence.

Johansen *v.* Pioneer Min. Co. (Washington), 137 Pacific, 1019, p. 1022, January, 1914.

A miner never assumes the risks of perils arising from the negligence of the mine operator, but assumes only such risks as are ordinarily incident to his employment after the mine operator has performed his whole duty with respect to furnishing a reasonably safe place to work and reasonably safe appliances.

Gambino *v.* Manufacturers' Coal & Coke Co. (Missouri Appeals), 164 Southwestern, 264, p. 266, February, 1914.

A miner does not assume the risk of negligence of the mine operator; and where it is the duty of a mine operator to inspect and care for the roof of the mine so as to render it safe, and the operator failed to do so, a miner injured by reason of such failure can not be said to have assumed also the duty of inspection or care as incidental to his employment.

Carnego *v.* Crescent Coal Co. (Iowa), 146 Northwestern, 38, p. 42, March, 1914.

UNEXPLODED BLASTS.

Whatever may be said as to dangers incident to the employment of miners, however forceful it may be contended that missed holes are frequent occurrences in mining operations and that such is known to the average miner, it can not be asserted that in modern mining operations, where one group of men follow and take up the work of a previous group, they should assume the risks attendant upon latent or immediate dangers left by those who had previously been engaged in prosecuting the work at the same place; and a miner, however diligent and painstaking in looking out and taking care of his own safety, is not expected to assume either the mistakes of those who preceded him or their failure to carry out the work in the usual customary manner; and this rule applies in the case of a missed hole left by a previous shift, hidden and obscure as it would necessarily be, and where the miner with the oncoming shift receives no warning or notice of its existence; and the failure of the mine operator to provide a regular system whereby notice of unexploded holes was bulletined or reported by the offgoing shift must be regarded as actionable negligence rendering the operator liable for a resulting injury.

Peterson *v.* Pittsburg Silver Peak Gold Min. Co. (Nevada), 140 Pacific, 519, p. 522, April, 1914.

See Panela *v.* Castile Min. Co. (Michigan), 144 Northwestern, 528, pp. 533–535, December, 1913.

See Conradsen *v.* Osceola Consol. Min. Co. (Michigan), 146 Northwestern, 638, April, 1914.

EXPLOSIVES.

Where mining operations are carried on by blasting and the work is done by different shifts of miners, all of the miners of one shift going out at a particular time and the other shift coming on, a miner in such new shift does not assume the risk of explosives remaining in missed holes, and the operator is chargeable with negligence, in case of an injury to a miner having no knowledge of any such unexploded charge, if he fails to adopt a proper and efficient method of communicating to the new shift any missed holes or unexploded charges.

Peterson *v.* Pittsburg Silver Peak Gold Min. Co. (Nevada), 140 Pacific, 519, p. 522, April, 1914.

Panela *v.* Castile Min. Co. (Michigan), 144 Northwestern, 528, p. 535, December, 1913.

EXPLOSIVES—DANGERS NOT DISCOVERABLE.

A miner working in a mine where dynamite is used for blasting and where it is permitted to be stored under statutory rules assumes the risk of all dangers incident to the storing of the dynamite as he saw it, but he does not assume the risk from a negligent method employed by the operator in thawing the dynamite where the thawer was out of his sight and with which he had nothing to do and had no knowledge of the dangers incident to the particular method employed in thawing the dynamite.

West Lake *v.* Keating Gold Min. Co. (Montana), 136 Pacific, 38, p. 44, October, 1913.

DANGERS NOT DISCOVERABLE.

Reasonable care and reasonable diligence in securing his safety is required on the part of a miner, to the end that he shall not by his own willful negligence bring about his own injury or death; but when a hidden danger is placed by others over whom he has no control, and from whom he may receive no warning or notice, in a place where he has to perform his services, he does not assume the risk thereof, and under this rule dangers arising from a missing blast can not be classified with dangers which are incidental to nature's hidden forces and which can not be known or foreseen by human prescience.

Peterson *v.* Pittsburg Silver Peak Gold Min. Co. (Nevada), 140 Pacific, 519, p. 522, April, 1914.

USE OF HAULAGE WAY.

It is the duty of a mine operator to exercise reasonable care to make a traveling or haulage way in a mine a reasonably safe place and to maintain it in that condition, and a miner using such traveling or haulage way does not assume the risk arising from the operator's failure to discharge that duty, unless the danger is obvious and the miner with knowledge of the danger, appreciation of the risk attending it, and without any assurance from the operator that it would be remedied, continued to use the way.

McInness *v.* Republic Coal Co. (Montana), 140 Pacific, 235, p. 237, April, 1914.

CHANGE OF WORK—UNKNOWN DANGERS.

Where a mine operator takes a miner from his regular working place and his regular work, to engage in other work in the mine which subjects him to increased or additional danger unknown to him, the miner does not assume the increased hazard or risk of the new place of work.

Domestic Block Coal Co. *v.* Holden (Indiana Appeals), 103 Northeastern, 73, p. 75, November, 1913.

KNOWLEDGE OF DANGER—DEFECTIVE APPLIANCES.

The fact that a cable drawing cars out of a mine was worn and had been broken on the end next to the car, but the end which broke had been put upon the drum and the other end used to fasten to the cars, was known to an employee in a mine whose business it was to assemble the loaded cars in a coal mine, fasten them together, and fasten the cable to the front car by which the loaded cars were drawn out of the mine, is not sufficient, as a matter of law, to charge the employee with the assumption of risk, where he believed the cable to be safe after it was so fixed and did not know of its unsafe condition, and where it was perfectly safe to be on the track if the cable did not break, and where in walking down the track for the purpose of having another car ready he was in the discharge of his duty.

Burnet Fuel Co. *v.* Ellis (Texas Civil Appeals), 162 Southwestern, 911, p. 913, January, 1914.

INJURY FROM VICIOUS MULE.

A driver of a mule in a mine assumes the dangers ordinarily incident to such an occupation, but he does not assume the risk where the mine operator knowingly furnishes him with a vicious mule, unsafe for use, and where the miner did not know of the viciousness and unsafeness of the animal; and the mine operator can not escape liability for an injury resulting from a vicious mule on the ground either that a mule is inherently and unreliably a dangerous animal or that a driver must be regarded as assuming any and all risks attending work with a mule.

Gatliff Coal Co. *v.* Wright (Kentucky), 163 Southwestern, 1110, p. 1112, March, 1914.

DANGERS IN ROOM NECK.

The danger from falling rock and débris in a room neck, the passageway leading from an entry in a mine to a room where the miner mines coal, is not one of the risks of the employment assumed by a miner, and where a miner was injured because of the operator's negligence in failing to repair or remedy the roof, after notice of the defective condition, then the danger therefrom was not a risk which the miner assumed.

Gambino *v.* Manufacturers' Coal & Coke Co. (Missouri Appeals), 164 Southwestern, 264, p. 266, February, 1914.

CONTRACTS RELATING TO OPERATIONS.

OPERATING CONTRACT—UNCERTAINTY.

A contract whereby a landowner and coal company employed the contractee to go upon its land and upon what was known as the Ida ore and Big Seam ore, and quarry therefrom and furnish to the coal company all the outcrop of such Ida ore and 6 feet of the Big Seam ore, the contract further providing that the contractee was to get out for and furnish to the coal company all the outcrop ore contained in what is known as the Ida ore and 6 feet of the Big Seam ore, in the property of the coal company, at a certain stated price per ton, is too indefinite and uncertain as applied to the subject matter of the contract or area sought to be designated to be enforceable, as the word "outcrop" of itself has no quality definitive of quantity or area in respect of the mineral, and used as a noun it describes that part of a mineral strata that lies at or near the surface of the earth, and used thus alone does not define or describe at what particular point, or at what line from the outer edge of the strata beneath the earth's surface at which it can be said the outcrop ends; and the provision that the contractee should get out all the outcrop ore designated as the Ida and the Big Seam ore has no force to render more certain, as to quantity, the amount of ore stipulated for extraction and delivery, as all outcrop only comprehends the entire outcrop, and the designation of the "6 feet of the Big Seam ore" and of "6 feet of the outcrop of the Big Seam ore" are alike ineffectual to impart requisite certainty to the contract; and the further fact that the contractee delivered under the contract and was paid for many tons of ore can not avail to avert the uncertainty in the particulars named.

Sloss-Sheffield Steel & Iron Co. *v.* Payne (Alabama), 64 Southern, 617–619, February, 1914.

PURCHASE OF MINING PROPERTY—RIGHT TO RESCIND FOR FRAUD.

A mining corporation organized to purchase certain mining property under an agreement to pay off certain liens and operate the property and pay the vendors certain royalties until a specified sum was paid can not rescind the contract on the ground of fraud where after knowledge of such fraud it retained possession of the property and treated the contract as valid, nor can it recover the amount paid in discharge of the liens where it fails to comply with the contract according to its terms and the contract is forfeited in an action by the vendors to recover the property.

Gordon-Tigar Min. & Reduction Co. *v.* Brown (Colorado), 138 Pacific, 51, p. 55, February, 1914.

CONTRACT OF PURCHASE—LIABILITY OF PURCHASER.

A mining corporation organized to purchase and purchasing certain mining properties under a contract by which it agreed to pay off certain liens on the mining property and erect a mill on the premises for the treatment of ores and operate the property without delay and pay certain royalty on the profits to the vendors until a specified sum was paid; and under the further agreement that if the property could not be worked profitably possession would be surrendered and the deeds, placed in escrow, returned and all moneys paid and all machinery and improvements made by the purchaser should be forfeited, is not entitled to rescind the contract on the ground of fraud and false representations, where the corporation after learning of the alleged fraud, treated the contract as valid and continued for 21 months to hold possession of the property, but placed no improvements whatever on the property and did not mine or sell any ore or operate any machinery for the treatment of ores, and it can not in an action by the vendors to recover the property for failure to comply with the contract recover money paid in discharge of the liens or expended by it in working the property, as it waived the right to rescind for the fraud, and it was not entitled to recover damages for the alleged fraud because of its failure to comply with the contract so as to entitle it to demand an absolute conveyance.

Gordon-Tigar Min. & Reduction Co. *v.* Brown (Colorado), 138 Pacific, 51, p. 53, February, 1914.

PREVENTING PERFORMANCE—LIABILITY.

A breach of a contract to mine coal, together with damages resulting therefrom, is sufficiently shown by a pleading stating that while the plaintiff was engaged in performing the contract on his part according to its terms and had on a certain day furnished defendant a statement of the work done under the contract, the coal mined, and also a statement of the number of linear yards of entry worked, and also of break-through or lateral entry work, showing the amounts due from the defendant to the plaintiff according to the terms of the contract, and that the defendant refused to pay the amounts so shown to be due for work done in driving such entries and break-through or lateral entry work, or any part thereof, and denied its liability to pay the same under the terms of the contract, and refused to carry out the contract on its part, and so conducted itself in other ways as to prevent the plaintiff from carrying out the contract on its behalf, whereby the plaintiff has lost and been deprived of divers gains and profits which might and otherwise would have arisen and accrued to him from the mining of such coal from the land described under the terms of the agreement.

Bare *v.* Victoria Coal & Coke Co. (West Virginia), 80 Southeastern, 941, p. 942, February, 1914.

BREACH OF CONTRACT TO MINE COAL—ELECTION OF REMEDIES.

Where a mine owner repudiated a contract with a miner to mine coal and refused longer to be bound thereby, the miner may (1) treat the contract as rescinded and recover on a quantum meruit to the extent of performance on his part; or (2) he may keep the contract alive for the benefit of both parties, being at all times himself ready and able to perform, and at the end of the specified time for performance sue to recover for the alleged breach; or (3) he may treat the repudiation as putting an end to the contract for all purposes of performance and sue for the profits he would have realized if he had not been prevented from performing; but the renunciation or repudiation on the part of the operator that will excuse performance and entitle the injured party to the remedies stated must be unequivocal and absolute and must deal with the entire performance to which the contract binds the other party, or must relate to such a material part thereof as to prevent performance by him.

Bare *v.* Victoria Coal & Coke Co., (West Virginia), 80 Southeastern, 941, p. 942, February, 1914.

BREACH OF CONTRACT TO MINE COAL—MEASURE OF DAMAGES.

In an action for damages for breach of a contract to mine coal, where the operator has wrongfully terminated the contract, the damages will not be limited to the bare account then due upon the contract, but the injured party may recover profits measured by the difference between what it would have cost to perform the contract and the contract price.

Bare *v.* Victoria Coal & Coke Co. (West Virginia), Southeastern, 941, p. 944, February, 1914.

GRUBSTAKE CONTRACT—CONSTRUCTION AND LIABILITY.

A grubstake contract entered into in 1898 and providing for a division of all the proceeds of the venture, and that wages earned should be treated as proceeds and providing that the agreement should continue during the entire time the prospecting party was in Alaska, is a continuing one and operates so long as the prospector was in Alaska, and the division of the proceeds provided for means net proceeds, and there is no liability on the part of the prospector where he returned from Alaska without any money whatever, though he had returned in the meantime twice and each time invested the funds he then had in mining machinery and appliances and both times returned to Alaska.

Troutman *v.* Polhill (Washington), 140 Pacific, 319, p. 320, April, 1914.

An action can not be maintained on a grubstake contract whereby the suing party advanced to the other two the sum of $500 "as part grubstake or outfit for prospecting and mining in Alaska," under an agreement that all finds or locations made by the two parties should be owned in equal parts by the three and that the two contracting parties would pay to the other one-third "of all proceeds derived from said venture," and that wages earned should be considered a find and divided equally, the agreement to continue during the time that such two parties were in the Klondike country of Alaska or British America, after a delay of 13 years, and where one of the contracting parties lost his life shortly after the two had proceeded to Alaska and where the remaining party subsequently returned with a considerable amount of money, invested this in an outfit and again returned to

Alaska, a second time returning with a small amount, invested this in machinery and returned to Alaska and subsequently came back penniless, and where the plaintiff made no attempt to excuse the delay in asserting the claim, and no claim had ever been made upon the surviving partner prior to the commencement of the action.

Troutman *v.* Polhill (Washington), 140 Pacific, 319, April, 1914.

CONVEYANCE OF COAL—IMPLIED COVENANT TO OPERATE.

A 99-year conveyance or lease of all coal and mineral rights, in certain described real estate, providing for the payment of a specified royalty for each ton of coal mined, but specifying no date for commencing mining operations and containing no clause forfeiting the instrument for failure to mine within a reasonable time, contains in effect an implied covenant by the lessee to begin mining within a reasonable time, and if he fails to do so, he will be presumed to have abandoned his right, and a court of equity will, at the instance of the lessor, cancel the lease as constituting a cloud on the title.

Chandler *v.* French (West Virginia), 81 Southeastern, 825, p. 827, May, 1914.

INDEPENDENT CONTRACTOR.

WHAT CONSTITUTES.

An independent contractor as applied to mining operations is one who exercises an independent employment and represents the mine operator only as to the results of his work and not as to the means whereby it is accomplished, and the independent contractor selects his men, provides equipment, provides the mode or manner of doing the work, and the relation is not qualified by a reservation which gives the operator the right to supervise the work for the purpose of determining merely whether it is being done in accordance with the contract; but the chief consideration is that the mine operator has no right of control as to the mode of doing the work.

Watson *v.* Hecla Min. Co. (Washington), 140 Pacific, 317, p. 318, April, 1914.

MASTER AND SERVANT—EMPLOYEE OF INDEPENDENT CONTRACTOR.

A coal-mine owner and operator occupies the position of a master to a miner employed by an independent contractor where such owner and operator had the oversight and control of the entry through which the employees of the independent contractor were compelled to pass and where it was not the duty either of the contractor or of his employees to make such entry safe and where the mine owner himself inspected the roof of the entry, but had failed to remove the dangerous part thereof which resulted in the death of the employee.

Big Hill Coal Co. *v.* Clutts, 208 Fed., 524, p. 525, November, 1913.

LIABILITY FOR NEGLIGENCE OF INDEPENDENT CONTRACTOR.

While a mine operator is not liable for an injury to a miner caused by the negligence of an independent contractor, yet where the contract relied upon to show the relation does not specify the character of the work other than that it shall be done in a workmanlike and substantial manner, and where the evidence casts a doubt as to whether the relation of independent contractor did not exist, it then becomes a question of fact to be determined by a jury in an action by an injured miner against the mine operator.

Watson *v.* Hecla Min. Co. (Washington), 140 Pacific, 317, p. 319, April, 1914.

MINER PAID BY TON.

A miner employed by a mine operator and paid by the ton for mining coal is not an independent contractor where the mine operator retains control over the manner and method of work; but in such case he is regarded as a servant whose compensation depends upon the amount of coal mined and is a miner entitled to the protection of the statute.

Interstate Coal Co. *v.* Trivett (Kentucky), 160 Southwestern, 728, p. 731, November, 1913.

Interstate Coal Co. *v.* Trivett (Kentucky), 160 Southwestern, 731, p. 732, November, 1913.

Big Branch Coal Co. *v.* Sanders (Kentucky), 166 Southwestern, 813, p. 814, May, 1913.

Employers' Indemnity Co. *v.* Kelly Coal Co. (Kentucky), 160 Southwestern, 914, p. 916, November, 1913.

LIABILTY OF OPERATOR FOR DEATH OF EMPLOYEE OF THIRD PERSON.

A coal mine owner and operator is liable for the death of a miner in the employ of an independent contractor who had intended to mine coal, but where it was shown the miner was killed in the cross entry by the fall from the roof of a block of slate, and where it also appeared that the operator exercised supervision and control over such cross entry and paid the wages of the miners, including that of the deceased miner, for the work performed in preparing such cross entry.

Big Hill Coal Co. *v.* Clutts, 208 Fed., 524, p. 525, November, 1913.

LIABILITY OF INDEPENDENT RAILROAD COMPANY.

A railroad company may be liable on the ground of negligence for the death of a miner in the employ of a coal company where the coal company owned a sidetrack which the railroad company had permission to use, and while the miner was engaged in repairing a car of the coal company the servants of the railroad company negligently pushed a car against the one beneath which the miner was working and where the miner was at the time in the line of his employment for the coal company and was not working for the railroad company; and he can not under the Pennsylvania law of 1868 be chargeable as a fellow-servant of the railroad employees.

Magnuson *v.* Pennsylvania R. Co. (Pennsylvania), 89 Atlantic, 462, p. 463, November, 1913.

CONSTRUCTION OF CONTRACT—PAROL EVIDENCE TO SHOW RELATION.

In an action by an injured miner against a coal-mine operator for damages, under the defense that the miner was working for an independent contractor operating under a written contract and agreement, the plaintiff is entitled to introduce evidence showing the real relation of the parties, and the rule which prohibits the introduction of oral evidence for the purpose of contradicting or modifying a written instrument does not apply, as the plaintiff was not a party to the agreement and would not be bound by its terms; and in such case the injured miner may show by oral testimony that the relation of master and servant subsisted between the mine operator and the alleged independent contractor and that the operator had direction and charge of the work being done by the alleged independent contractor.

Watson *v.* Hecla Min. Co. (Washington), 140 Pacific, 317, p. 318, April, 1914.

NOTE.—The court after broadly stating the rule proceeds to cast doubt upon the rule by saying: "If the contract is certain and definite the question whether a person operating under it is an independent contractor is for the court; but where the terms of the contract are doubtful, or are rendered doubtful by the introduction of oral testimony the question generally becomes one for the jury." The rule stated is further nullified by a quotation from Fehrenbacher *v.* Oaksdale Copper Min. Co. (65 Wash., 134; 117 Pacific, 870), as follows: "Where the contract is certain the question of whether a person operating under it is an independent contractor or a mere servant is a question of law for the court. But where the terms of the contract are in doubt the relation of the parties is generally a question for the jury."

LIABILITY TO EMPLOYEE OF INDEPENDENT CONTRACTOR.

A mine operator may, on the ground of negligence, be liable to an employee of a person under contract with such operator whereby such person delivered coal into buggies and drove entries for a stipulated price, paying such employee and one or more other men out of the contract price, the earnings of the assistants being credited upon the books of the operating company and payment therefor being made by the operator, and where the company furnished power and equipment and the mine foreman had authority to discharge anyone employed in the mine, as a mine operator can not escape liability for negligence by such an arrangement.

Big Branch Coal Co. *v.* Sanders (Kentucky), 166 Southwestern, 813, p. 814, May, 1914.

MANAGING COMPANY—INDEPENDENT CONTRACTOR.

A coal company can not escape liability for an injury to a miner caused by its alleged negligence on the ground that it was not operating a coal mine but was merely a holding company and that the coal mine was in fact operated by another company, and that the two companies were separate and distinct, where the same officers and stockholders constituted both companies and where the evidence shows that metal checks were given to the employees in payment of labor and supplies bearing the name of the defendant company.

Stearns Coal & Lumber Co. *v.* Tuggle (Kentucky), 164 Southwestern, 74, p. 75, March, 1914.

PARTNERSHIP AGREEMENTS.

PARTNERSHIP AGREEMENTS—SETTLEMENT OF ACCOUNTS.

An action by the administrator of a deceased miner against his partner for an accounting for moneys expended in the development of the claim will be defeated by proof that the defendant repudiated the agreement at a particular time and gave notice that he would not contribute longer to the enterprise and thereupon the partners settled and adjusted the accounts to that date.

Goldsmith *v.* Murray (Montana), 138 Pacific, 187, December, 1913.

CONSTRUCTION AND RIGHTS.

Under an agreement between the plaintiff and defendant by which the former advanced money to the latter for his expenses in procuring oil leases and options and was to have an equal interest in such leases and options, even though the defendant was to give all his time to such business, this did not prevent him from joining in the organization of a corporation for the purpose of developing oil property, where this took no part of his time and did not conflict with the partnership business and where it appeared that the plaintiff refused to put any money into any drilling propositions and a subsequent agreement by which plaintiff was no longer to furnish money, of itself terminated the original agreement and the plaintiff could have no interest in the corporation subsequently organized, even though defendant's interest in the corporation would have been partnership property if acquired prior to the termination of the partnership agreement.

Hamman *v.* Emerson (135 Louisiana), 65 Southern, 765, p. 767, May, 1914.

SUIT FOR AN ACCOUNTING.

Mining partners in a suit for an accounting should each be charged and credited with the sums received and paid out according to their respective interests, and one partner is entitled to a credit and the other should be charged with one-half of a sum paid by one partner for an interest owned by the partners equally.

Kleesattel *v.* Orr (Washington), 141 Pacific, 355, June, 1914.

METHODS OF OPERATING.

EXPERT EVIDENCE.

While the rule is that where all the circumstances can be fully and adequately described to the jury, and are such that their effect can be understood by all men, without special knowledge or training, then the opinion of witnesses, expert or otherwise, is not admissible; but where the roof of a tunnel in a mine had been cracked from the effect of a shot fired by the miner, and where an inexperienced miner was unable to pry down the loosened parts with a bar, and where he was subsequently injured by the fall of this loosened material, expert miners may give their opinion as to whether experience and knowledge of the sounding test were necessary to determine whether the roof of the tunnel in such condition was liable to fall, and the evidence is admissible on the theory that all men are not familiar with the operation of coal mines or with the various conditions that might or might not indicate danger, and are not as capable as experienced miners in determining whether a situation described to them would or would not obviously indicate a danger.

Carney Coal Co. *v.* Benedict (Wyoming), 140 Pacific, 1013, p. 1018, May, 1914.

JUDICIAL NOTICE.

While neither a court nor jury can properly take judicial notice of how a coal mine should be operated, or what is practicable and good usage among prudent operators, yet where the negligence of an operator is shown to be gross, resulting in the death of a miner, neither courts nor juries may properly shut their eyes, forswear their judgment, and await the coming in of expert testimony concerning some physical fact or omission of duty patent to everyone.

National Fuel Co. *v.* Maccia (Colorado), 139 Pacific, 22, p. 25, March, 1914.

PREVENTING OPERATIONS—INJUNCTION.

TRADE UNIONS—RIGHT OF EMPLOYEES TO STRIKE.

An employee, or any number of employees, in the absence of a contract to work a definite time, has a right to quit the service of the employer without any reason or for any reason he may regard satisfactory to himself; and employees of a coal company have a right to protest to the employer against the employment or retention of a nonunion employee and to make the discharge of such nonunion employee a condition to their continuation in his employment, and that unless such nonunion employee is discharged the union employees will strike, or the equivalent, will simultaneously cease to work; and if under such circumstances the nonunion employee is discharged by the common employer he has no cause of action against either the union as an organization or the members thereof as individuals.

Roddy *v.* United Mine Workers of America (Oklahoma), 139 Pacific, 126, p. 127, January, 1914.

ENJOINING STRIKERS—PLEADING.

A bill for an injunction filed by a mining corporation against the Western Federation of Miners is sufficient for the purpose where, after formal declaration, it avers that the general strike was called and inaugurated by the defendant in the copper mining district of Lake Superior on a certain day; that 4,000 miners in the complainant's employ not allied with the defendant refused to participate in the strike and endeavored to continue work; that the defendant by threats and violence interfered with and drove them from their work, stopped the pumps at the mine, causing the latter to partly fill with water, thus forcing a suspension of work; that a condition of violence and lawlessness developed in the district where the strike prevailed beyond the power of the civil authorities to control; that from the day of the inception of the strike the members of the federation did unlawfully combine and conspire together with the unlawful purpose and by illegal and unlawful means to prevent the employees of the mining company from working at the mines, and to force the cessation of all operations, and that such members have assaulted and beaten many of the employees of the mining company and continued daily to make such assaults and beatings and threats of deadly harm, and do, systematically, by threats, intimidations, force, violence, assaults, picketing, threatening parades, riotous and threatening gatherings in large numbers, and by other unlawful means, interfere with and molest and disturb, without authority of law, the miners employed by the mining company.

Baltic Min. Co. *v.* Houghton (Michigan), 144 Northwestern, 209, December, 1913.

MINING LEASES.

LEASES GENERALLY—CONSTRUCTION.

COVENANTS CONSTRUED IN FAVOR OF LESSEE.

In oil and gas leases the compensation of the lessor is generally a royalty, and the covenants to be performed by the lessee which relate to the right to drill or explore for oil or gas are generally construed most strongly in favor of the lessor; but this rule has its limitations, and when a lessee has faithfully performed all his covenants and has discovered oil in paying quantities and the lessor is receiving the royalty as the lease contemplates, the lessor can not then invoke this rule to aid him in dispossessing the lessee, and the lessee having performed his covenants he thereby obtained a vested interest in the oil and gas in the leased premises because of his exclusive right to drill, and the lessee holds such interest as security against the lessor.

Burgan *v.* South Penn Oil Co. (Pennsylvania), 89 Atlantic, 823, p. 825, January, 1914.

NATURE AND CONSTRUCTION—CONSIDERATION AND RIGHTS OF PARTIES.

The holder of a State mining lease conveyed to another a one-fifth interest, the grantee at the time signing and delivering to the grantor a writing to the effect that under certain conditions the grantor would take back one-half of the interest conveyed within six months of the date of the sale, at the option of the purchaser, and such agreement is binding as an option agreement and is based on a sufficient consideration and the seller is bound by such contract though he did not in fact sign it, and the contract is capable of specific enforcement.

Gregory Co. *v.* Shapiro (Minnesota), 145 Northwestern, 791, p. 793, February, 1914.

LICENSE TO MINE—KNOWLEDGE OF CONDITION—FORFEITURE.

A license to mine for a specified time can not be forfeited for the failure to pay a royalty amounting to no more than $4.30; nor can such a license be forfeited because the licensee made a verbal agreement with two persons by which they were to carry on mining operations "six months at a time" for a percentage of the ore mined, where the transaction was not a sale or assignment of the mining license, or any interest in the same, but the licensee was still the sole owner of the mining license and did not lose control of the mining operations; nor can the licensor forfeit the license for the failure of the licensee to do continuous mining, where it appeared that no work was done during the latter part of October and during the month of November, and where the licensor was aware of the fact and made no complaint at the time.

Gates *v.* Steckel (Missouri), 161 Southwestern, 1185, p. 1186, January, 1914.

LICENSE TO MINE—RIGHTS OF LICENSEE—REVOCATION.

While a mere licensee acquires no estate or interest in the land, mines, or minerals, and had no possession sufficient to enable him to maintain a possessory action, yet the right to mine can not be revoked at will and he can not be arbitrarily deprived of this right under his license in the absence of some substantial violation of the terms and conditions imposed by the mining lease.

Gates *v.* Steckel (Missouri), 161 Southwestern, 1185, p. 1186, January, 1914.

STATE LEASE—ASSIGNMENT.

The statute of Minnesota (R. L. 1905, sec. 2493) provides that an assignment of mining leases shall be signed by both parties, executed in the presence of two witnesses, duly acknowledged, with the approval of the auditor thereon; but this law is not a statute of frauds and was not intended to make invalid contracts relative to the property evidenced by a State mining lease when executed and conformable to the requirements of contracts relative to real property, and an agreement to repurchase within a specified time a certain interest in a mining lease, though not in writing, may be enforced.

Gregory Co. *v.* Shapiro, 145 Northwestern, 791, p. 794, February, 1914.

COAL LEASES.

CONSTRUCTION—ASSIGNMENT.

A coal lease or contract providing that "the words 'trustee and lessee' as understood herein shall be construed to mean successors, heirs, executors, and assigns" evinces an intention on the part of the parties to the contract to make the contract or lease transferable by assignment, and there is nothing to indicate that the term "assigns" should have reference alone to the assignee of the lessee.

Young Coal Co. *v.* Hill (Arkansas), 165 Southwestern, 292, p. 293, March, 1914.

LEASE OF COAL WITH RIGHT TO MINE—CONSTRUCTION AND EFFECT.

A lease of all the coal underlying a tract of land with the right to mine and remove the same at a given price per ton as royalty is equivalent to a sale of the coal in place.

Trustees, etc., Kingston *v.* Lehigh Valley Coal Co. (Pennsylvania), 88 Atlantic, 768, p. 769, June, 1913.

FAILURE TO PAY ROYALTIES—DAMAGES.

A coal-mining lease providing that the lessor was to receive a certain stipulated royalty per ton for all coal mined and requiring the lessee to keep an accurate account of the coal mined and to develop the coal on the premises leased, and expressly providing that the failure of the lessee to pay the royalties stipulated should operate as a forfeiture of the lessee's rights, may be forfeited by the lessor and the lessee's rights terminated on failure of the lessee to pay the royalties according to the terms of the lease; and the lessor is entitled to recover damages for failure to prosecute the mining operations with diligence, and such damages are recoverable as incidental to the accounting for the unpaid royalties.

Pollak *v.* Stouts Mountain Coal & Coke Co. (Alabama), 63 Southern, 531, p. 532, November, 1913.

ASSIGNMENT—SUBLETTING—LIABILITY OF ASSIGNEE.

A lessee parting with his interest in the whole of the leasehold estate for the balance of his term, or with his interest in the part of the demised premises for the entire term, is in effect an assignment of lease, and the assignee becomes an assignee of the term with the rights and liabilities incident to such a position, and it is immaterial by what kind of an instrument or conveyance the term is so disposed of, if the lessee parts with his entire interest in the whole or part of the premises and the assignee of a coal lease becomes liable for the royalty on the coal mined to the original lessor, and does not occupy the position of a mere sublessee.

Pennsylvania Min. Co. *v.* Bailey (Arkansas), 161 Southwestern, 200, November, 1913.

ADJUDICATION OF TITLE—EFFECT.

An adjudication of title in an action for injunction to prevent a lessee of coal lands from wrongfully mining coal, and a determination by a court that the lease under which the mining was prosecuted was a lease of the surface only and that the coal in place belonged to the reversioner, is not res adjudicata in a subsequent action by the reversioner against the lessee for damages for the wrongful mining of coal prior to the judgment enjoining further operations.

Trustees, etc., Kingston *v.* Lehigh Valley Coal Co. (Pennsylvania), 88 Atlantic, 763, p. 767, June, 1913.

LIABILITY OF SURETY OF LESSEE.

The fact that a lessor of a mining lease simply forebore to sue the lessee from time to time on his past due indebtedness for royalties, where such forbearance was without any consideration, does not release a surety of the lessee from his obligation to make good the violation of the lease on the part of the lessee; nor is the lessor, on the failure of the lessee to pay the royalties according to the lease, bound to declare the lease forfeited, as the forfeiture was at the option of the lessor, and the failure of the lessor to declare a forfeiture and to bring suit for royalties that had accrued and that were permitted to remain due more than a year was but forbearance for past due indebtedness without consideration, and did not release the surety.

Young Coal Co. *v.* Hill (Arkansas), 165 Southwestern, 292, p. 293, March, 1914.

LIABILITY FOR COAL USED IN OPERATIONS.

Under a custom prevailing in the anthracite coal region of Pennsylvania coal used by a lessee in the operation of the mine is not subject to royalties.

Trustees, etc., Kingston *v.* Lehigh Valley Coal Co. (Pennsylvania), 88 Atlantic, 768, p. 769, June, 1913.

MINERALS REMOVED UNDER SUPPOSEDLY VALID LEASE.

Where coal was mined by the assignee of a 999-year lease under the belief that the lessee and his assignees were the owners of the coal, but it had been judicially determined that the lease conveyed the surface of the land only, the reversioner in an action for damages for the wrongful mining of the coal can not invoke the rule of treble damages under the Pennsylvania act of 1876, as the act does not apply to such cases, but the reversioner is limited to an action for ordinary damages as for an innocent trespass.

Trustees, etc., Kingston *v.* Lehigh Valley Coal Co. (Pennsylvania), 88 Atlantic, 768, p. 770, June, 1913.

ACTION FOR COAL WRONGFULLY MINED—STATUTE OF LIMITATIONS.

A reversioner under a 999-year lease may sue to protect the estate and may sue and recover for the unlawful mining and conversion of coal by the tenant or his assignee, but such an action is barred by the statute of limitations after six years, and the statute of limitations begins to run against the reversioner's right from the time he discovered, or by due diligence should have discovered the wrongful mining of the coal.

Trustees, etc., Kingston *v.* Lehigh Valley Coal Co. (Pennsylvania), 88 Atlantic, 763, p. 765, June, 1913.

REFORMATION DENIED.

A lessor is not entitled to the reformation of a lease granted by him for the operation of a coal mine providing for a stipulated royalty on coal mined where the lessee subsequently assigned the lease to a corporation organized for the purpose of operating the mine, on the ground of mutual mistake in that he had a separate agreement with the lessee that in the event the lease was assigned to a third person an increased royalty should be paid, where it appeared that the corporation at the time of its organization and at the time of the assignment of the lease had no notice of such independent agreement.

Rockport Coal Co. *v.* Carter (Kentucky), 163 Southwestern, 734, p. 736, February, 1914.

OIL AND GAS LEASES.

CONSTRUCTION—RIGHTS AND LIABILITIES GENERALLY.
DEVELOPMENT IMPLIED.
FORFEITURE AND CANCELLATION.

CONSTRUCTION—RIGHTS AND LIABILITIES GENERALLY.

DUTIES AND LIABILITIES IMPOSED.

Where the object of the operations contemplated by parties to an oil and gas lease is to obtain a benefit or profit for both lessor and lessee, neither is, in the absence of stipulations to that effect, the arbiter of the extent to which or the diligence with which the operation shall proceed; but both are bound by the standard by what in the circumstances would be reasonably expected of operators of ordinary prudence, and the development and protection of lines which is implied when the lease is silent is such as is usually found in the same business of an ordinarily prudent man, neither the highest nor the lowest, but about the average; and where under such a lease at the completion of the first well the lessor and lessee by agreement changed the terms of the lease, the effect of which was a waiver by the lessor of the implied condition for further development on other portions of his land, and therefore a limitation upon the production on the whole tract, the lessee must, notwithstanding the amended agreement, if conditions subsequently arise which require the lands to be protected, use reasonable diligence in this behalf and sink as many wells as the exercise of due diligence should suggest to an ordinarily prudent person engaged in the same undertaking under the same circumstances; and on his fraudulent refusal to develop and protect the premises the lessor may resort to equitable relief, and in such case he does not have an adequate remedy at law.

Jennings *v.* Southern Carbon Co. (West Virginia), 80 Southeastern, 368, p. 370, November, 1913.

RIGHTS AND LIABILITIES.

An oil lease imposing on the lessee, under certain conditions, the duty to drill a certain number of wells, may be canceled by the lessor for failure to drill as provided for by the lease; but the potestative condition can not be invoked as to that part of the lease and of the leased premises where the lessee had drilled a number of wells, but not the number required.

Caddo Oil & Min. Co. *v.* Producers' Oil Co. (134 Louisiana), 64 Southern, 684, p. 686, March, 1914.

A lease of land for oil and gas purposes in the usual form, providing for payment of royalties and the drilling of one well within a stated time, and providing also that if the lessee felt justified in drilling more than one well then the parties were to share equally in all expenses of such additional drilling, and providing also that if operations for oil or gas ceased for a period of 60 days the lease should become null and void, may be forfeited in an action by the lessor for that purpose in case operations have ceased for more than the 60-day period, and the lessor is not bound to tender the lessee any sum or one-half of the cost of the drilling of a subsequent well, as the drilling of any additional wells depends upon the lessee's feeling justified in so doing, and as the cost of such drilling is indefinite the lessor's liability would arise only when the lessee proceeded to drill the second well.

Ditman *v.* Keller (Indiana), 104 Northeastern, 40, p. 41, February, 1914.

A lease of land for a period of five years and as much longer as the premises should be operated for oil and gas, for the purpose of operating for oil and gas and mineral, and of laying pipe lines, building tanks and stations, the lessor to receive one-half of the profits from all wells, is not ambiguous and will be interpreted and enforced according to the plain meaning of its provisions where nothing is shown that changes the rights of the parties as therein expressed.

Ditman *v.* Keller (Indiana Appeals), 104 Northeastern, 40, February, 1914.

The rule that oil and gas leases are construed most strongly against the lessee and in favor of the lessor does not apply in an action sounding in damages on the ground of an alleged trespass by the lessee after the expiration of the lease.

Cooke *v.* Gulf Refining Co. (135 Louisiana), 65 Southern, 758, p. 760, May, 1914.

NATURE AND ESTATE.

An oil and gas lease in the usual form providing that the lessee should hold the premises for the term of five years and as much longer as gas and oil is found in paying quantities on the premises, conveys to the lessee a freehold estate, for the reason that it may continue indefinitely.

Daughetee *v.* Ohio Oil Co. (Illinois), 105 Northeastern, 308, p. 310, June, 1914.

WANT OF MUTUALITY AND CONSIDERATION.

A lease of land for oil and gas for a period of 40 years imposing no duty upon the lessee except to pay a nominal royalty on oil and gas produced, and not requiring the lessee to expend any money in prospecting or developing oil or gas lands, lacks both consideration and mutuality and the lessor may withdraw therefrom at any time before performance by the lessee, as such instrument is but a lease option.

Davis *v.* Riddle (Colorado), 136 Pacific, 551, p. 552, November, 1913.

MUTUALITY AND VALIDITY.

A condition in an oil and gas lease in the usual form granting to the lessee the right to operate the premises for oil and gas, the lessee reserving the right to abandon the premises whenever it desires to cease operation and to remove the property placed thereon by it, at discretion, is clearly potestative and makes the execution of the lease depend upon the will of the lessee, thereby destroying the obligation which the lessee had assumed and which was the legal tie that gave the lessor the right to enforce the lease, and as the money consideration was merely nominal it follows that there being no obligation resting on the lessee, and therefore no consideration moving to the lessor, there was no contract; but if the lessee has actually complied with and discharged the obligation which, but for the potestative condition, would have been imposed upon him, and the lessor accepted and profited by the advantage resulting therefrom, the lessor can not while retaining such advantage, or in case of his inability to reinstate the status quo, be permitted to repudiate the obligations thereby assumed and have the lease canceled and set aside.

Caddo Oil & Min. Co. *v.* Producers' Oil Co. 134 (Louisiana), 64 Southern, 684, p. 687, March, 1914.

PLEADING PERFORMANCE OF CONDITIONS.

A lease of land for the purpose of operating thereon for oil and gas and in consideration of which the lessee agrees to pay the lessors the one-fifth part of all the oil produced and saved therefrom, and further agrees to pay $150 a year for each well secured on the premises, when utilized off of the premises, and the lessees were to commence a well within 10 days from the day of the lease, is sufficiently complied with where the lessee began the drilling of a well for oil within the stated time and prosecuted the drilling diligently for more than three months, reaching a depth of 1,950 feet, drilling through the oil-producing sand in the particular district and at the expense of $7,000, but without discovering oil or gas; and, subsequently and while still in possession of the leased premises the lessees, for the purpose of further developing the premises for oil and gas, procured the right to and did proceed to drill on adjoining premises and within 300 feet of the line of the leased premises, a well producing oil in large quantities, and the lessor could not while the lessees were so in possession and so developing the leased premises execute a new and valid lease of the same premises to a third person having notice and knowledge of the original lease, and in an action by the lessees of such first lease to have declared void and have canceled such second lease it is sufficient as a matter of pleading to allege generally the performance of all the conditions to be by them performed according to the terms of the lease.

Cahill *v.* Pine Creek Oil Co. (Oklahoma), 136 Pacific, 1100, November, 1913.

NATURE OF TITLE—VESTED RIGHTS.

Under a lease granting a right to operate for oil and gas the title is inchoate and granted for purposes of exploration only until oil or gas is found, and if not found no estate vests in the lessee, and his title, such as it is, ends when the unsuccessful search is abandoned; but if oil or gas is found, then the right to produce becomes a vested right and the lessee will be protected in exercising it in accordance with the terms and conditions of his contract.

Burgan *v.* South Penn Oil Co. (Pennsylvania), 89 Atlantic, 823, p. 826, January, 1914.

VESTED RIGHTS—ABANDONMENT.

A landowner leased three several tracts of land and granted the exclusive right to produce oil and gas from each as long as these could be produced, with a covenant on the part of each lessee to commence drilling within 30 days and diligently prosecute the same to completion, and to commence a second well within 60 days and prosecute the same in like manner, and to commence drilling a third well within 60 days from the completion of the second, and on failure to commence the second well within the specified time the lessee should forfeit all the land except 8 acres around the first well, and on failure to commence the third well within the specified time he should forfeit all the land except 17 acres around the first and second wells, and there can be no forfeiture where the original lessee completed three wells in the time specified, and on the performance of the covenant in this manner each lease becomes valid and binding as to the entire tract therein described and the lessee is entitled to hold the entire tract and continue sinking other wells thereon so long as either oil or gas is produced, and the abandonment of any one of the three wells after it ceased to be profitable was not an abandonment by the lessee of his vested right to take the oil in and under the tract out through other wells.

Burgan *v.* South Penn Oil Co. (Pennsylvania), 89 Atlantic, 823, p. 826, January, 1914.

VESTED RIGHTS OF LESSEES.

An owner of land having leased the same for development for oil and gas on certain stated terms and conditions, can not, while the lessee is in possession of the lease premises performing the conditions of the lease and diligently engaged in developing the land as the lease contemplated, make a valid lease of the premises to a third person with notice of the original lease and with knowledge of the development of the same by the lessees.

Cahill *v.* Pine Creek Oil Co. (Oklahoma), 136 Pacific 1100, November, 1913.

INTEREST AND RIGHTS GRANTED BY LEASE.

Under an oil and gas lease providing that if oil, gas, coal, water, and other minerals be found in paying quantities, but, none the less, if the grantee discontinues the work or fails to develop the oil wells, he is to be held to have abandoned all the lands leased, except 10 acres in a square to be held by the grantee for 25 years; and further in the event oil, gas, water, or other minerals are produced in paying quantities, the lessee can not claim the 10 acres in a square in the absence of proof that he has discovered oil, gas, coal, or other minerals in paying quantities, as this right is dependent upon the condition that the enumerated substances shall be found in paying quantities.

Brown *v.* Producers' Oil Co. (134 Louisiana), 64 Southern, 674, p. 676, March, 1914.

LEASE OF OIL LANDS.

A lease or agreement reciting that for and in consideration of a nominal sum and other considerations of mutual covenants and other agreements set out, the lessor did thereby lease to the lessee certain described lands, and grant to the lessee the exclusive right to sink shafts, to drill wells, and to extract any and all kinds of minerals, especially petroleum from the land, the lease to extend for a term of 20 years unless sooner forfeited, and the lessee in consideration thereof agreed to incorporate a company for the operation and development of the leased property before commencement of active operations on the property and to commence active work of boring for oil not later than a certain specified date, and to prosecute such labors diligently, is a lease of the land itself and is not an ordinary oil and gas lease by which the lessor remains in possession and control of the land, giving the mere right of entry to the lessee to begin the prosecution of search for oil; and the discovery of oil was not a prerequisite to the existence of a cause of action on the part of the lessee or its assigns for the failure of the lessor to place the lessee in possession of the property.

Kline *v.* Guaranty Oil Co. (California), 140 Pacific, 1, p. 3, April, 1914.

METHOD OF MEASURING GAS.

An oil and gas lease provided that for any gas well producing gas of marketable quantities a semiannual sum was to be paid as rental, to be ascertained by gauging such well every six months in the casing in which it was completed, and if the well showed for the first minute of the gauging a pressure of 200 pounds or more the rental for the ensuing six months was to be $250, and for less amounts of pressure smaller sums of rental in proportion were to be paid; and the method of measurement and computation and the right to recover is not lost from the fact that the company operating the gas well inserted a smaller tube inside the casing that necessarily changed the pressure and made it impossible to gauge the gas in the original casing, as provided by the terms of the lease, where the evidence shows that by taking the pressure in the tubing and using a well-known mathematical formula the practical equivalent could be obtained for the pressure in the casing, and where the evidence also shows that the calculations of the minute pressures of gas are only practically accurate and the calculation of the equivalent pressure in the smaller tube was necessarily of the same general character.

Addleman *v.* Manufacturers' Light & Heat Co. (Pennsylvania), 89 Atlantic, 674, January, 1914.

APPLICATION OF STATUTORY RULES.

The statutes of Louisiana are silent on the subject of mineral rights and contracts for the reason that minerals under and within the soil of Louisiana were not in contemplation of the lawmakers; and when parties enter into a contract of lease of oil lands containing terms inconsistent with, if not antagonistic to, the laws and jurisprudence of the State, and they did so under the advice of learned and competent counsel, a court will be slow in holding one of the parties to a technical bad faith in insisting upon a compliance with the terms of the lease as interpreted by it and its legal adviser, or in continuing in possession under a provision which continued the lease in force and effect so long as oil or gas may be produced in paying quantities, and especially so when there is a difference of opinion as to what may be properly termed paying quantities.

Cooke *v.* Gulf Refining Co. (135 Louisiana), 65 Southern, 758, p. 758, May, 1914.

APPLICATION OF EXISTING LAWS.

Oil and gas leases are apart by themselves and there is scarcely any comparison between them and the ordinary farm and house lease, though there is some resemblance to coal or solid mineral leases; and the law with reference to sales and leases in ordinary legislative enactments can not be always applied to oil leases, as these are the nature of both sale and lease, and the law with reference to good or bad faith can not be applied with the same degree of certainty as would attend the interpretation of the law with reference to an ordinary trespass.

Cooke *v.* Gulf Refining Co. (135 Louisiana), 65 Southern, 758, p. 759, May, 1914.

EFFECT OF EXCEPTIONS AND RESERVATIONS.

A clause in a conveyance or lease of land and the oil and gas therein "excepting and reserving from this conveyance and the warranty herein all of the estate, right, title, and interest in and to the premises above described which were conveyed by said Louisa D. Cracraft, deceased, to James Townsend Russell by and (an) instrument in writing bearing date of January 28, 1901, and also excepting and reserving all the rents, royalties, and compensation reserved by and agreed to be paid to said Louisa D. Cracraft by said James Townsend Russell in and by said written agreement," is in effect a reservation of the oil and gas in place, though the lease therein referred to was, at the suit of the lessor, by decree in her favor, after the drilling of a profitable gas well on the land, forfeited and removed as a cloud on her title.

Updegraff *v.* Blue Creek Coal & Land Co. (West Virginia), 81 Southeastern, 1050, May, 1914.

OWNERSHIP OF GAS.

A gas and oil lease for a tract of land in the ordinary form with an agreement to furnish free gas to the lessor, and a further agreement to pay on the part of the lessee a certain specified sum yearly until a well is completed, does not by its terms convey to the lessee any title to the gas under the land, but rather creates in the lessee the right to reduce it to possession by means of drilling wells, and when so reduced to possession it becomes the personal property, the absolute title to which is in the lessee, subject to the terms of the lease, and the lease extends to all gas under the entire tract of land; but the title thereto remains in the lessor subject to the lessee's right to explore for it and reduce it to possession; and by a deed by the lessor for any part of the premises to a third person the lessor and grantor parts with his title to so much of the land included in such conveyance, and conveys to his grantee the qualified ownership in the gas under the tract so conveyed; but the grantee of such part of the land covered by the original lease can have no right or interest whatever in any gas produced through or by a well on the residue of such leased land, even though such gas or some part of it may have flowed immediately or remotely from underneath the land conveyed to him.

The owner of the fee of land owns everything that goes to make up the realty, and natural gas beneath the surface is a part of the realty and the owner of the fee is the owner of the gas; and by reason of the fugitive character of natural gas the owner of the land is owner of the gas only in a qualified sense, and owns it only while it remains beneath the surface of his land, but if by its natural tendency to flow it escapes to the lands of an adjoining proprietor such ownership then ceases; but this qualified ownership in the gas authorizes the landowner to reduce it to possession by sinking wells on his land and thus permit it by natural means or its own ordinary pressure to flow to the surface and into a receptacle he may prepare to receive the same, and when thus reduced to possession through a well, and regardless of whether it came from beneath his own land or remotely from the lands of an adjoining proprietor, it then becomes personal property, the absolute ownership of which is in the landowner.

Fairbanks *v.* Warrum (Indiana Appeals), 104 Northeastern, 983, p. 986, April, 1914.

MINING LEASE WITH OPTION TO PURCHASE.

An ordinary mining lease, with an option to purchase, providing for development work in general, but with no provisions for specific buildings or other permanent improvements except the work done in the usual operation of an active mine, does not create the relation of vendor and vendee.

Milwaukee Gold Min. Co. *v.* Thompkins-Cristy Hardware Co. (Colorado), 141 Pacific, 527, p. 529, June, 1914.

LEASE EXECUTED BY LIFE TENANT—AUTHORITY OF REMAINDERMAN.

A remainderman has no power to authorize a widow holding a dower interest in land, or life tenant, to execute an oil and gas lease upon the land unless such authority is given by an instrument in writing, duly signed by him as the owner of the fee.

Prout *v.* Hoy Oil Co. (Illinois), 105 Northeastern, 26, p. 29, April, 1914.

LEASE BY LIFE TENANT.

Neither a widow owning a dower interest in land nor a life tenant has the power to make a lease of land under which oil or gas or other minerals can be removed from the land as against the remainderman.

Prout *v.* Hoy Oil Co. (Illinois), 105 Northeastern, 26, p. 29, April, 1914.

VALIDITY—FRAUD—WITHHOLDING INFORMATION.

Where the lessor and the lessee of an oil and gas lease stand upon equal footing and where there is no fiduciary relation of any character existing between them, but they deal at arms' length, the lessee is not bound to give the lessor any information in his possession, but he has the right to remain silent without violating any rule of law or equity and without subjecting himself to a charge of fraud; but if the lessee volunteered to give information for the purpose of influencing the lessor, then it became his duty to tell the truth and the whole truth; and a lease executed under such circumstances is valid and can not be nullified by the execution of a subsequent lease.

Prout *v.* Hoy Oil Co. (Illinois). 105 Northeastern, 26, p. 30, April, 1914.

PRESUMPTION AS TO LOCATION OF OIL WELL.

Under the allegation in a complaint to the effect that the owner of a certain tract of land executed an oil and gas lease thereon, and that the lessee drilled on said tract a gas well which produced gas in paying quantities, and further averring that subsequently the owner conveyed a certain portion of the first-described tract, it will be presumed, in the absence of an allegation, that the gas well mentioned was on the residue of the said tract rather than on the part conveyed.

Fairbanks *v.* Warrum (Indiana Appeals), 104 Northeastern, 983, p. 986, April, 1914.

RIGHT OF LESSEE TO CONSTRUCT ROAD—LIABILITY FOR DAMAGES.

A lessee having the right under his lease to go upon certain described land of the lessor and bore and develop said land for oil and gas, with the necessary usual and convenient rights therefor, has a right to build a road over the land where the building of such road is necessary to enable him to haul material for his rig and tools and machinery for drilling; but if after building such road he in good faith abandons the contemplated exploration for oil and gas before drilling a well, he is liable to the lessee for damages to the land caused by the building of such road.

Coffindaffer *v.* Hope Natural Gas Co. (West Virginia), 81 Southeastern, 966, p. 967, May, 1914.

FRAUDULENT ALTERATION.

The lessee in an oil and gas lease can claim no rights under a lease where, according to the evidence and circumstances, he made a fraudulent change in the date for the purpose of extending the term and life of the lease, and where no operations were begun within the original lifetime of the lease.

Southern *v.* South Penn Oil Co. (West Virginia), 81 Southeastern, 981, April, 1914.

ESCROW—DELIVERY TO LESSEE.

There can be no delivery of an oil and gas lease in escrow where the lease is complete in itself and the delivery was made to the lessee, as such a delivery is absolute, notwithstanding any verbal agreement between the parties.

Gaffney *v.* Stowers (West Virginia), 80 Southeastern, 501, p. 504, December, 1913.

WHEN TENANT MAY DENY TITLE OF LANDLORD.

A lessee holding leases of two adjacent landowners took possession of a particular part of the leased lands of one lessor and drilled an oil-producing well and operated the same for more than 10 years, and during such time paid the oil royalties to the lessor under whose lease the entry was made, and during all of such time maintained a sign in large letters on the walking beam, in plain view of public highways and railroads, showing under whose lease the well was drilled and operated, is not, after the expiration of the period of the statute of limitations estopped to deny the title of the other lessor in an action by such lessor for an accounting, on the ground that the well was on his land; and in order to work an estoppel in such case on the part of the lessee the lessor claiming the land must do more than show the lease contract, but must show actual possession by himself of the particular land involved and that the lessee was let into possession by him and not by the lessor of the other tract.

Lockwood *v.* Carter Oil Co. (West Virginia), 80 Southeastern, 814, p. 817, February, 1914.

FAILURE OF TITLE—RECOVERY FOR MONEY PAID.

Money paid as rent under an oil and gas lease may be recovered back as money paid on a consideration that has partially failed, where the lessee could not enter because of the doubtful title in the lessor, if the money was paid without knowledge of the facts showing defect in the title; but if the money was paid voluntarily with knowledge of all the facts, but under a mistake as to the law arising thereon, then it can not be recovered.

Gaffney *v.* Stowers (West Virginia), 80 Southeastern, 501, p. 504, December, 1913.

BREACH OF COVENANT—LIABILITY OF LESSOR.

The lessor of an oil and gas lease is not liable in an action of assumpsit for the breach of a covenant for quiet enjoyment where the lease expressly excepted the minerals retained for the sake of a compromise with a certain named corporation, and on the ground that the lessor had wholly failed to place the lessee in possession of the minerals, and where it appeared that no person had been in possession of the oil and gas by drilling or otherwise, between the date of the lease and the date of its alleged surrender, and no one was shown to have set up any claim to the oil or gas in any way to have prevented the lessee from taking possession, and where the lessee made no effort to obtain possession, and no act of obstruction on the part of the lessor was shown, and where the only matter relied upon as constituting an eviction or breach of the covenant was a lack of title to the oil and gas in the lessor.

Gaffney *v.* Stowers (West Virginia), 80 Southeastern, 501, p. 503, December, 1913.

LIABILITY OF LESSOR FOR FAILURE TO DELIVER POSSESSION.

A person executing a pretended lease for land of which he had no title, because of his own default in the performance of a prior agreement with the owner of the legal estate, and imposing conditions upon the lessee which required of him the expenditure of money in advance of the taking possession of the leased premises, and so acting in bad faith, knowing the impossibility of performance on his part, is liable to the lessee either in an action for a breach of the covenant for peaceable possession, or for breach of an agreement to convey an estate in real property, and the damages for the breach in either case would be those which would ordinarily and proximately follow from the breach of such a contract under the peculiar circumstances, which were known to both parties.

Kline *v.* Guaranty Oil Co. (California), 140 Pacific, 1, p. 4, April, 1914.
See Gaffney *v.* Stowers (West Virginia), 80 Southeastern, 501, December, 1913.

DEFECTS CURED BY OPERATIONS.

A condition in an oil lease to the effect that if the lessee should fail to commence operation within 24 months then the lessor might declare the lease null and void by giving written notice to the lessee, subject to the right of the lessee to the continuance of the oil and mineral rights granted by the lease, by the payment to the lessor of rental at the rate of 50 cents per month per acre, until operations shall have been begun, may have made the lease potestative in the beginning, but the defect was cured by the subsequent commencement of the work by the lessee at the instance and request of the lessor, and after the work had actually commenced and after the discovery of oil on the adjacent premises by the operations of the lessee, the lessor can not then declare the lease null and void, and the assignee of the lessor, after the commencement of such operations by the lessee, has no greater rights than the original lessor and is bound by all the equities between the lessor and lessee.

Hudspeth *v.* Producers' Oil Co. (134 Louisiana), 64 Southern, 891, p. 893, March, 1914.

LIABILITY OF LESSEE FOR BREACH OF COVENANT—LESSOR'S RIGHT TO SUE.

The lessor in an oil and gas lease for a term of five years, and containing the usual terms and conditions and requiring the lessee to drill a well within a stated time and to pay certain stipulated royalties, may sue the lessee for a breach of any express or implied covenant of the lease resulting in damages to him; and a cause of action immediately arises in his favor, and he is not required to wait until the abandonment of the premises or expiration of the lease to bring his action, and the remedy in such case is not forfeiture but a right to sue for a breach of the contract.

Daughetee *v.* Ohio Oil Co. (Illinois), 105 Northeastern, 308, p. 310, June, 1914.

BREACH OF COVENANT—MEASURE OF DAMAGES.

A lessor leasing to an oil company land one body aggregating 2,200 acres and various tracts in the vicinity aggregating 3,000 acres, in consideration that the oil company should develop the land by boring for oil and gas and should drill a well to a depth of 1,200 feet, is entitled to recover as damages for a breach of the lease in failing to drill the well to the depths specified, and in the lessee's abandoning the well before reaching the specified depth, the reasonable market value of the leases, as this must be regarded as the actual value paid by the lessor to have the well drilled as specified.

Henry Oil Co. *v.* Head (Texas Civil Appeals), 163 Southwestern, 311, November, 1913.

In an action by a lessor against the lessee of an oil and gas lease for damages for breach of a covenant, in that the lessee failed to diligently develop the premises after the discovery of oil in paying quantities, the lessor is not prevented from recovery because the damages are speculative or conjectural, and the rule is that while the law will not permit witnesses to speculate or conjecture as to the possible or probable damages, still the best evidence of which the subject will permit is receivable, and this is often nothing better than the opinion of well-informed persons on the subject matter under investigation; and the lessee in such an action is not immune from damages though he has committed no fraud and has acted in good faith and has not drained oil from the lessor's premises by means of wells on other adjacent lands; nor is he permitted to escape for a failure to drill and operate additional wells if, acting on his own judgment, he believes that it will not be profitable for him to do so, as his determination in such case is not final, and such a lease can not be construed to save the lessee harmless on his arbitrary refusal to further explore and develop the leased premises; and in such case the lessor is not required to prove that oil and gas have actually been lost to him by being drawn from the leased premises through wells on adjacent premises or by some wrongful or fraudulent act of the lessee, but under such a lease it is clearly the contemplation of the parties and the primary object in making the lease that the lessee shall go on and drill additional wells, market the product, and pay the lessor his royalties thereon, and the lessee in effect agrees to do this in order that the lessor can realize on the value of the product.

Daughetee *v.* Ohio Oil Co. (Illinois), 105 Northeastern, 308, p. 311, June, 1914.

FRAUD OF OFFICER—LEASE TO HIMSELF.

A person purchasing a majority of the stock of a mining corporation for the fraudulent purpose of obtaining possession of its mines can not, after electing himself president and managing officer, make a lease of the mining property to himself and take possession of and operate the company's mine, and can not in this manner acquire any equities in the property or growing out of the unlawful contract as against the corporation or a stockholder.

Franklin *v.* Havalena Min. Co. (Arizona), 141 Pacific, 727, p. 730 (June, 1914).

INJUNCTION TO PREVENT OPERATION.

A preliminary injunction to prevent a lessee from operating for oil and gas under a lease should not be granted where the evidence shows that the lessee has been in undisputed possession of the land and has drilled thereon a number of wells, built tanks, established pipe-line connection, and is actually producing large quantities of oil.

Ingram *v.* Bream (Pennsylvania), 88 Atlantic, 880, June, 1913.

DEVELOPMENT IMPLIED.

DILIGENCE REQUIRED IN OPERATION.

Where the object of the operations under an oil and gas lease is to obtain a benefit or profit for both the lessor and lessee, neither is in the absence of stipulations to that effect the arbiter of the extent to which or the diligence with which the operation shall proceed, but both are bound by the standard of what under the circumstances would be reasonably expected of an operator of ordinary prudence having regard to the interest of both.

Indiana Oil, Gas & Development Co. *v.* McCrory (Oklahoma), 140 Pacific, 610, p. 613, May, 1914.

PRESUMPTION AS TO DEVELOPMENT.

From the fact that lessors in oil and gas leases usually receive no consideration except in royalties from oil or gas after their discovery the presumption always is that such leases are made for the purpose of immediate development unless the contrary appears from the terms of the lease itself.

Burgan *v.* South Penn Oil Co. (Pennsylvania), 89 Atlantic, 823, p. 825, January, 1914.

IMPLIED OBLIGATION TO DEVELOP.

An oil and gas lease, the only consideration of which on the part of the lessee was that he should drill for oil, imposed the implied obligation on him that he would use reasonable diligence in operating the premises after they had been developed, and where oil had been found on the land there arose an implied obligation on the part of the lessee to put down as many wells as may be reasonably necessary to secure the oil for the common advantage of both lessor and lessee.

Caddo Oil & Min. Co. *v.* Producers' Oil Co. (134 Louisiana), 64 Southern, 684, p. 690, March, 1914.
Brown *v.* Producers' Oil Co. (134 Louisiana), 64 Southern, 674, p. 676.

IMPLIED COVENANT TO DEVELOP.

An oil and gas lease reserving to the lessor royalties in kind and in money on the oil produced and saved and the gas used off the premises as the consideration and inducement for the lease, and which, while expressly requiring the drilling of one well during the first five years, does not expressly define the measure of diligence to be exercised after the expiration of that period, contains, however, a covenant on the part of the lessee, arising by necessary implication from the nature of the lease and the character of the mineral sought, that if during the term allowed for original exploration and development oil or gas is found in paying quantities the work of development and production shall be continued with reasonable diligence, to the end that the extraction of the oil and gas from the leased lands shall be mutually advantageous and profitable to the lessor and lessee; and this implied obligation is as effectual as if expressed, and if it arises from the language of the lease it is controlling, and if the lessee fraudulently fails or refuses to conduct such proper operations equity will, at the suit of the lessor, decree either total or partial cancellation of the lease, according to the facts and circumstances averred and proved.

Jennings *v.* Southern Carbon Co. (West Virginia), 80 Southeastern, 368, p. 368, November, 1913.

IMPLIED COVENANT—BINDING EFFECT.

Leases for oil and gas are subject to the implied covenants that the lessee will do all that is necessary to carry into effect the purposes and objects of the lease, and there is an implied covenant, in the absence of an express agreement to begin work within a certain time, to begin the operations within a reasonable time; and this implied covenant is, after oil or gas has been discovered, as effectual and forceful as if it were expressed in direct terms, as implication is but another term for intention; and the practically universal interpretation of oil and gas leases is that in the absence of an express covenant there arises a legal implication that the lessee will drill as many wells as will afford sufficient protection against drainage and otherwise so develop the leased premises as to serve the mutual benefit of both lessor and lessee.

Jennings *v.* Southern Carbon Co. (West Virginia), 80 Southeastern, 368, p. 369, November, 1913.
Chandler *v.* French (West Virginia), 81 Southeastern, 825, p. 828, May, 1914.

DISCOVERY OF OIL—IMPLIED COVENANT TO DEVELOP.

The lessee of an oil lease in legal form, after a test well has been drilled and oil found in paying quantities, is bound to proceed with reasonable diligence to put down as many additional wells as may be necessary to properly develop the premises and to operate such wells and pay the lessor the royalty provided by the lease, and in the absence of an express covenant to this effect a covenant will be implied.

Daughetee *v.* Ohio Oil Co. (Illinois), 105 Northeastern, 308, p. 309, June, 1914.

CONTRACT FOR DEVELOPMENT—FORFEITURE.

A lease for oil and gas for the sole and only purpose of prospecting, drilling, or operating for oil, gas, petroleum, coal, or other minerals for a term of 20 years, and as long thereafter as such oil, gas, coal, or other minerals are found in paying quantities, reserving to the lessor a certain stipulated royalty on the oil and the customary royalty on the other minerals, required the lessee to begin drilling within 30 days and to prosecute the work with due diligence until a well is completed, and, providing that a failure to drill a well as provided shall render the lease null and void, can not be forfeited where the lessee did commence and complete a well within the specified time and obtained oil in paying quantities, as he thereby acquired a vested right under the lease for the time stipulated and was not subject to forfeiture for failure of the lessee to further drill and develop the leased premises.

McAfee *v.* Grubb (Texas Civil Appeals), 164 Southwestern, 925, p. 926, March, 1914.

IMPLIED COVENANTS.

A lease of certain lands granted "all the oil and gas" under the lands described together with the right to enter at all times for the purpose of drilling and operating, with the right to erect and maintain structures, pipe lines, and machinery necessary for the production and transportation of oil and gas and give the right to use sufficient water, oil, and gas to run the necessary engines in the prosecution of the business, and reserved to the lessor substantial royalties in kind and in money on the oil produced and saved and on the gas used off the premises, the lease indicating that the promise of such royalties was the controlling inducement to the grant, and while expressly requiring that drilling commence within 90 days from the date of the lease, but not expressly defining the measure of diligence to be exercised by the lessee in the work of development and production after the expiration of the stated period, it is held to contain a covenant on the part of the lessee arising by necessary implication from the nature of the lease and the stipulations therein contained, to the effect that if during the term of the lease either oil or gas is found in paying quantities then the work of development and production shall be continued with reasonable diligence and along lines as will be reasonably calculated to make the extraction of oil and gas from the leased land of mutual advantage and profit to the lessor and lessee.

Indiana Oil, Gas & Development Co. *v.* McCrory (Oklahoma), 140 Pacific, 610, p. 613, May, 1914.

FORFEITURE AND CANCELLATION.

FAILURE TO OPERATE.

A lease of land for oil and gas for a period of 40 years, imposing upon the lessee no duty whatever save and except the nominal one of paying to the lessor as royalty 1 per cent of the net proceeds derived from all oil or gas obtained, should the lessee see fit to develop the land, may be a valid lease, but will be forfeited at the suit of the lessor where it is shown that the lessor for a period of 18 months or more made no move to prospect for oil or do anything whatever in that direction and gave no explanation of his delay in that behalf, as such unexplained delay is sufficient to work the forfeiture of a lease.

Davis *v.* Riddle (Colorado), 136 Pacific, 551, November, 1913.

FAILURE TO OPERATE—TERMINATION OF LEASE.

Where an oil and gas lease provided that in case the grantee should sink a well and discover oil or gas or other mineral within the specified time, then the lease should be in full force and effect for the period of 20 years from the discovery of such mineral and as much longer as minerals are produced in paying quantites, the lease itself must terminate when the lessee ceases to operate, as the term was dependent upon a continuance of operation by the lessee.

Brown *v.* Producers' Oil Co. (134 Louisiana), 64 Southern, 674, p. 676, March, 1914.

FORFEITURE FOR BREACH OF COVENANT.

While courts of equity generally refuse to aid in the enforcement of a forfeiture, yet a court of equity will decree a forfeiture of an oil and gas lease on account of a breach of an implied covenant to diligently operate and develop the property when such forfeiture will effectuate justice and is more consonant with the principles of right, justice, and morality than to withhold equitable relief.

Indiana Oil, Gas & Development Co. *v.* McCrory (Oklahoma), 140 Pacific, 610, p. 614, May, 1914.

ACTION TO FORFEIT LEASE—DAMAGES.

In an action by a lessor to forfeit a lease of land for oil and gas purposes for breach of an implied covenant to diligently prosecute the work, a court can not decree damages together with a judgment of forfeiture where the rules by which damages are established are so indefinite and uncertain as to amount at most to a mere guess, and where the production from the wells on the lease in suit, as well as that from the wells on the adjoining land, was unequal and varying, and where from wells drilled into the same sand and only a few hundred feet apart the production was so variant that it would be absurd for a court to fix any stated amount of damages for failure of the lessee to operate diligently.

Indiana Oil, Gas & Development Co. *v.* McCrory (Oklahoma), 140 Pacific, 610, p. 615, May, 1914.

FORFEITURE—COMPLIANCE WITH CONDITION.

An oil and gas lease giving the lessee the right of developing, producing, and marketing oil and gas for a term of five years and as long thereafter as oil and gas should be found, the lessee to complete a well within one year or pay an annual rental of 25 cents per acre until a well should be completed, the lessor to have one-eighth of all oil produced and saved on the premises and the lessee to pay $100 per annum for each well from which gas was marketed, can not be cancelled at the suit of the lessor where the annual rental had been paid and where the lessee had drilled a well and was engaged in pumping it, though the production was unprofitable and the lessor had received no royalty.

Gillespie *v.* Ohio Oil Co. (Illinois), 102 Northeastern, 1043, p. 1044, October, 1913.

A lease of land for oil and gas purposes in the usual form and providing that the lessor should receive one-half of the profits from all wells, and providing that in case the lessee should cease operations for oil or gas for a period of 60 days then the lease should become null and void at the option of the lessor, indicates that development is the central purpose, and if a forfeiture is provided for in case of a failure to develop according to the terms of the lease a forfeiture will be declared and enforced where the lessor brings himself within the provisions authorizing such forfeiture.

Dittman *v.* Keller (Indiana Appeals), 104 Northeastern, 40, February, 1914.

FAILURE OF LESSEE TO PERFORM.

A grantee in a conveyance or lease that provides that in consideration of the payment of the sum of $105 the grantors agree to grant and convey by deed of general warranty to the said grantee the undivided one-sixteenth part of the oil and one-half of the gas within and underlying the land described, and containing a provision to the effect that "it is hereby agreed and understood that the essence of this agreement is the payment of the sum of $200 for each well to be paid within 90 days after said wells are tapped and tested, and a failure to pay the same within the time hereinbefore specified is to render this contract null and void, and the parties of the first and second part are to stand relieved from all damages and responsibility for the nonexecution and nonfulfillment of this contract, by reason of the failure to make said payment, within the time before specified," can not maintain an action for an accounting against the lessor and a subsequent lessee, for oil or gas produced, if he fails to show payment of the sum stipulated and performance by him of all other conditions precedent, as the payment of the $200 for each well within the time stipulated was a condition precedent to the assertion of any right in the oil or gas by the grantee or lessee.

Freeman *v.* Carnegie Natural Gas Co. (West Virginia), 81 Southeastern, 572, p. 574, April, 1914.

UNCERTAINTY IN DESCRIPTION—CANCELLATION OF INSTRUMENT.

A complaint in an action by a senior lessee of oil and gas to cancel a lease held by a junior lessee covering part of the same land is not insuffcient because the descriptions are too vague and uncertain where the description in the complaint and the lease filed as an exhibit bounds the senior lessee's land on every side by reference to lines of other landowners and names the quantity bounded as 340 acres, and the leased premises so described necessarily include the oil underlying the various tracts composing such 340 acres, and a description of land by references to lines of other landowners is a sufficient identification if the lines adopted can be identified on the ground.

South Penn Oil Co. *v.* Gardner Oil & Gas Co. (West Virginia), 82 Southeastern, 203, May, 1914.

PERIOD AND TERMINATION.

An oil and gas lease which stipulates that it is to continue during the time that gas or oil are found in paying quantities is at an end and may be annulled when the time during which the lessee has the right to exploit the land has expired and no oil or gas has been found.

Cooke *v.* Gulf Refining Co. (135 Louisiana), 65 Southern, 758, p. 759, May, 1914.

MINING PROPERTIES.

TAXATION.
TRESPASS.
TITLE.
CONTRACTS OF SALE.
STATUTORY LIENS.

TAXATION.

CONSTRUCTION OF STATUTE—RECOVERY OF TAX.

The right of appeal granted by the Wisconsin income-tax law (sec, 1087*m*–13, Stat. 1911), authorizing a corporation feeling aggrieved by the decision of the State Tax Commission regarding the assessment of its income, shall be granted the same rights of hearing and appeal as are now granted corporations assessed by said commission, refers to a review before the tax commission of its preliminary decisions as to the amount of income on which the corporation must pay income tax, and does not authorize a corporation to sue to recover an income tax illegally levied and collected.

Montreal Min. Co. *v.* State (Wisconsin), 144 Northwestern, 195, December, 1913.

CLAIM OF UNJUST ASSESSMENT—REMEDY.

A mining corporation whose property is duly assessed for taxation by the assessing officer can not assert that the assessment was unjust in an action by the State to collect the taxes assessed without first making application to the county board of equalization at the time fixed by the statute, although the assessing officer was in fact guilty of fraudulent and corrupt conduct.

Arizona Copper Co. *v.* State (Arizona), 137, Pacific 417, December, 1913.

MINERALS RESERVED FROM CONVEYANCE.

A reservation in a deed executed by the Northern Pacific Railroad Co. contained the clause "excepting and reserving unto the grantors, its successors and assigns, forever, all mineral of any nature whatsoever upon or in said land, including coal and iron, and also the use of such surface ground as may be necessary for exploring for and mining or otherwise extracting and carrying away the same," constitutes property that is subject to taxation under the laws of Montana.

Northern Pacific R. Co. *v.* Mjelde (Montana), 137 Pacific, 386, p. 387, December, 1913.

MINING CLAIMS SUBJECT TO TAXATION.

The constitution of Montana (art. 12, sec. 3) provides that all mines and mining claims, whether placer or lode, containing gold, silver, copper, lead, coal, or other mineral deposits, when purchased from the United States, shall be taxed at the price paid the United States therefor, unless the surface ground of such mine or claim is used for other than mining purposes and has a separate and independent value for such other purposes, in which case the surface ground so used for other than mining purposes shall be taxed at its value for such other purposes as provided by law; and all machinery used in mining and all property and surface improvements in connection with a mine or a mining claim, having a separate and independent value, as well as the annual net proceeds of all mines and mining claims, are subject to taxation, is not a provision exempting property from taxation, but is a revenue measure and fixes an arbitrary valuation upon the surface of patented mining claims as such, and makes the net value of the proceeds the standard by which the value of a mine shall be determined; but neither an unworked mining claim nor an operated mine is relieved of the revenue upon the basis thus established, and a nonproducing mine is not exempted though there is an implication that the nonproducing mine, independently of its surface, does not have any value for the purpose of taxation and that minerals while in a mine or mining claim have no taxable value.

Northern Pac. R. Co. *v.* Mjelde (Montana), 137 Pacific, 388, p. 387, December, 1913.

WHAT CONSTITUTES A MINE.

Under article 12, section 3, of the constitution of Montana providing for the taxation of mines and mining claims, the sense in which the term "mine" is used, if there is any doubt, must be determined in favor of a definition under which public revenue will be raised rather than a meaning which will defeat the purpose of the constitutional provision, as it was the evident intention of the convention forming the constitutional provision to make such mining properties subject to taxation and not to exempt them from taxation.

Northern Pac. R. Co. *v.* Mjelde (Montana), 137 Pacific, 386, p. 390, December, 1913.

MINES AND MINING CLAIMS—WHAT CONSTITUTES FOR TAXATION.

Under the constitution of Montana providing for the taxation of all mines and mining claims the term "mining claim" as therein used indicates a tract of land to which the right of possession or title has been acquired pursuant to the acts of Congress relating to the disposition of mineral lands, including coal lands, and a mine, independently of the surface, in the revenue sense as there employed, is a mineral deposit, whether metallic or nonmetallic, developed to the point of production and actual yielding or capable of yielding proceeds; and an undeveloped body of ore is not a mine though title to it was secured under the mining laws, but is merely a part of the real estate itself; and the word "mine" in this section of the constitution does not include hidden, unknown, or undeveloped deposits of ore or coal.

Northern Pac. R. Co. *v.* Mjelde (Montana), 137 Pacific, 386, p. 391, December, 1913.

RESERVATIONS OF MINERAL TAXABLE AS PROPERTY.

A reservation in a deed conveying real estate to the effect that the grantor reserves all minerals of whatsoever kind, together with the right to use the surface to explore for and mine and remove all minerals found, is not under the constitution of Montana taxable as a mine, but the presumption is, in the absence of proof that such a reservation has some appreciable value, though it does not produce revenue, and such a reservation constitutes an interest in real estate and is taxable as such under the general statute providing for the taxation of all property, and the fact that the value of such property may be difficult to determine can not operate to defeat the purpose of taxation.

Northern Pac. R. Co. *v.* Mjelde (Montana), 137 Pacific, 386, p. 391, December, 1913.

ASSESSMENT—GROSS PROCEEDS.

Under a statute authorizing mining property to be assessed at a sum equal to one-fourth of the gross proceeds unless the net proceeds shall exceed them in value, the gross proceeds of a mine can not be construed to mean the gross value of the ores disposed of, and the assessor must determine the sum received by the mine operator for his ore by deducting from its gross value all expenses mentioned in the statute except the cost of extracting it from the mine; and the statute means to give to the terms "gross value" and "gross and net proceeds" the distinctive meanings which, as usually employed, they convey.

Paxson *v.* Cresson Consolidated Gold Min., etc., Co. (Colorado), 139 Pacific, 531, p. 532, March, 1914.

The statute of Colorado (secs. 5619–5620) requires the operator of a producing mine to make out and deliver to the county assessor a statement showing the name of the mine, the name of the owner, the number of acres, the number of tons of ore extracted during the preceding year, the gross value of the ore extracted, the annual cost of extracting the same, not including salaries of officers or agents not actively engaged in mining, the actual cost of transportation to place of reduction or sale, and the net proceeds after deducting all such expenses; and the assessor shall for the purpose of assessment for taxes value such mine at a sum equal to one-fourth of the gross proceeds for the preceding year, and this statute requires the assessor from the statement furnished to ascertain the gross and net proceeds, but he is not required to value the mine at one-fourth of the gross value of the ore shown by the statement, but he is to ascertain the gross proceeds of the mine and value it at one-fourth of that amount. unless the net proceeds exceed that sum, as the legislature evidently intended that the "gross value" of ore extracted from a mine and the "gross proceeds" of such mine had different meanings.

Paxson *v.* Cresson Consolidated Gold Min., etc., Co. (Colorado), 139 Pacific, 531, p. 532, March, 1914.

TAXATION OF MINING CLAIMS—INVALID INCREASE.

Where 65 separate mining claims containing a total area of 636 acres were returned and assessed as one parcel by the proper assessing officer, the county board of supervisors, sitting as a board of equalization, has no power under the statute of Arizona (R. S. 1887, par. 2654) to segregate from this area eight separate mining claims and impose on these an additional assessment, without first determining that such tract was improperly assessed as a whole and causing it to be assessed and raised in subdivisions in such manner as to preserve the right of the taxpayer to discharge the lien of taxes upon any one of the several tracts; and such increased assessment must not be arbitrary but must be based upon evidence as to value; and in case the assessment of any given tract is increased the increased amount must be set opposite such tract together with a statement of the original valuation.

Arizona *v.* Copper Queen Min. Co., 233 U. S., 87, p. 92, April, 1914.

SEVERANCE OF SURFACE AND MINERALS—IMPROPER ASSESSMENTS.

The owner of lands containing coal that was assessed in 1903 for taxation for its full cash value and on the same basis as other lands of the same nature and fertility in the same neighborhood were assessed may recover taxes for 1904 and 1905 paid under protest where it appears that the auditor of the county, without authority or right, placed upon the tax duplicate an assessment for the years 1904 and 1905 against such lands an amount largely in excess of the original valuation and assessment, which increased valuation and assessment was on the alleged ground that the owner had sold and conveyed a separate estate in the coal underneath such land, as the auditor had no authority to make such increased valuation, but in case of a sale of a part or severance he can only apportion values already fixed.

Riggs *v.* Board of Commissioners, Sullivan Co. (Indiana), 103 Northeastern, 1075, January, 1914.

MINERAL INTERESTS TAXABLE.

Where mineral interests in real estate have been separated from the surface and are separately owned such mineral interests are land and taxable as such, especially so under the statute of Minnesota (G. S. 1913, sec. 1973), which provides whenever any mineral, gas, coal, oil, or other mineral interests are owned separately from the surface such mineral, gas, coal, or oil may be assessed and taxed separately from the surface rights and may be sold for taxes in the same manner as other interests are sold for taxes.

Washburn *v.* Gregory Co. (Minnesota), 147 Northwestern, 706, p. 707, May, 1914.

TAX CERTIFICATE—MINERAL INTERESTS.

A tax certificate based upon tax proceedings in which the property is described by its Government description without any reference to mineral interests owned separately from the surface does not cover or include such mineral interests.

Washburn *v.* Gregory Co. (Minnesota), 147 Northwestern, 706, p. 707, May, 1914.

TRESPASS.

MINING COAL UNDER INVALID LEASE—LIABILITY.

In an action against an assignee of a lessee under a 999-year lease of coal lands who believed the lease conveyed the coal in place, but where it was legally determined that the lease conveyed the surface only, the measure of damages for mining and converting the coal is the fair market value of the coal in place, if there is a market price for the coal in place in the pit or mine; but in the absence of evidence to fix the value of coal in place, then the value at the pit's mouth may be determined by deducting all the cost of bringing the coal to the pit's mouth; and in the absence of evidence showing the value either in place or at the pit's mouth then its value at a distant market may be determined by deducting from the value at such market the cost of taking the coal to the market; but the true rule is the value of the coal in place, and the alternative methods of measuring the damages are exceptions to the rule.

Trustees, etc., Kingston *v.* Lehigh Valley Coal Co. (Pennsylvania), 88 Atlantic, 763, p. 766, June, 1913.
Stark *v.* Pennsylvania Coal Co. (Pennsylvania), 88 Atlantic, 770, June, 1913.

MINING COAL UNDER SUPPOSEDLY VALID LEASE—VALUE OF COAL IN PLACE.

In an action against a lessee operating under a supposedly valid lease for wrongful mining of coal the measure of damages is the market value of coal in place, and in such a case it is proper to allow a recovery on the basis of royalty value where the mine is so located with reference to a market that it has a market value for operating purposes at a price per ton, or on a royalty basis, and this value must be ascertained as of the time when the trespass was committed and must be the actual market value of the coal in place at that time and not the prospective value in the future when conditions may be changed and the value of coal increased.

Trustees, etc., Kingston *v.* Lehigh Valley Coal Co. (Pennsylvania), 88 Atlantic, 763, p. 767, June, 1913.
Stark *v.* Pennsylvania Coal Co. (Pennsylvania), 88 Atlantic, 770, June, 1913.

CONVERSION OF COAL—PROOF OF TITLE.

An action of trover for the wrongful mining and conversion of coal may be maintained by a plaintiff either in the actual or constructive possession of the land, and in such an action legal title may be proved in order to show constructive possession essential to the maintenance of the action; but such proof can not be made and trover can not be maintained where the evidence shows that the defendant was in the adverse possession of the land.

Pearce *v.* Aldrich Min. Co. (Alabama), 64 Southern, 321, p. 322, February, 1914.

LIABILITY—JOINT WRONGDOER.

A railroad company appropriating land for a right of way over and across lands within and under which is located a mine is liable for trespass where it authorized a contractor constructing its roadbed to go upon the land of the mine owner outside of its right of way and cut down the land to a point within 4 feet of the top of the mine, and where the contractor in the process of cutting down the land blasted into and injured the mine, and the fact of the contractor's wrong by blasting into the mine does not relieve the railroad company, as its liability arises on the theory that he who counsels, advises, abets, or assists another to commit a tort or joins in its commission is responsible for all the injury done, whether specifically authorized or not, and can not excuse himself from liability because the particular injury complained of was occasioned by a contractor in connection with the wrongful acts authorized.

Cincinnati, etc., R. Co. *v.* Simpson (Indiana), 104 Northeastern, 301, p. 306, February, 1914,

LIABILITY FOR PRODUCING GAS AFTER EXPIRATION OF LEASE.

An action for damages for trespass by a lessor against the lessee under a lease of lands for gas and oil, for damages for trespass after a well had been drilled and after the expiration of the lease, and after the lease has been judicially annulled, can not be regarded as a suit for damages to the land for the reason that the well is an advantage, but it must be construed as a suit for so much gas that plaintiff alleges the defendant took from the land; but until the gas was produced the plaintiff had the exclusive right to reduce the gas below the surface of the land to possession and to become the owner thereof, and that right was leased to the defendant, and if because of a wrong interpretation of the lease the defendant produced gas from plaintiff's land and converted it to his own use, he may be held for the value of such gas, and the damages can not be limited to the lease price of a paying well, where there was no such paying well during the life of the lease; and the lease in such case can not be the law between the parties; and accordingly the plaintiff is entitled to recover damages from the defendant for the usurpation of and abuse by him of the exclusive right of drilling, which right was the property of the plaintiff, the owner of the soil, and of appropriating the gas produced by him from the soil of the plaintiff, and the value of such gas at the well is the measure of damages for which the defendant must be held liable, and the real value of the gas used by plaintiff is its value in place, but as the plaintiff was not the owner of the gas at that time and where the expense of drilling the well and the cost of its equipment constituted the cost of the production of the gas, and such cost exceeds the highest possible estimate of the value of the gas at the mouth of the well, the defendant would owe the plaintiff nothing whatever by reason of the alleged trespass, and the defendant can not be held for exemplary damages where it appears that he acted in good faith and under the advice of competent counsel before the commencement of the action.

Cooke *v.* Gulf Refining Co. (135 Louisiana), 65 Southern, 758, p. 760, May, 1914.

POLLUTION OF WATERS.

In an action by a lower riparian owner against a mining company for damages on the alleged ground that the coal company was maintaining a mining camp and operating a coal washery upon its superior estate and depositing the coal washings and other débris in the stream, which were thereupon carried down upon plaintiff's land, rendering the water unfit for use, the plaintiff can not recover damages for slight inconvenience from the mere discoloration of the water, or the deposit of coal or other débris therein, nor can he recover damages on the alleged ground that the water was unfit for any use where the evidence does not tend to show that the plaintiff had in fact been deprived of the use of the water for domestic purposes or for the use of his live stock during the 12-month period immediately before the commencement of the suit.

Parsons *v.* Tennessee Coal, Iron & R. Co. (Alabama), 64 Southern, 591, February, 1914.

MEASURE OF DAMAGES.

In an action by a landowner against a mining company for damages for wrongfully depositing tailings on his land, the measure of damages is the difference in the value of the land with and without the value of the tailings thereon.

Robinson *v.* Moark Nemo Consol. Min. Co. (Missouri Appeals), 163 Southwestern, 885, p. 886, February, 1914.

MITIGATION OF DAMAGES.

In an action against a mining corporation for trespass for wrongfully depositing tailings from its mills upon the land of the complainant the mining company may show in mitigation of damages that it had abandoned the tailings and that the tailings themselves were of some value because of the ore contained therein and that there was a market value for such tailings, that contractors would purchase and remove them from the land, and that the value of such tailings was fully or at least partially equal to the damages to the land.

Robinson *v.* Moark Nemo Consol. Min. Co. (Missouri Appeals), 163 Southwestern, 885, p. 886, February, 1914.

TITLE.

QUIETING TITLE TO MINING MACHINERY.

Under an option contract a grantee acquired possession of a mining claim with the privilege of operating the mine during the life of the option, and under an agreement to place upon the mine machinery and improvements sufficient to operate the same bound itself not to dispose of such machinery or remove the same from the mine without the written consent of the grantor, and if payment was not made according to the option the mining machinery should become the property of the vendor as liquidated damages, the grantor may, on failure of the purchaser to make the payment as provided, maintain an action to quiet his title to such mining machinery as against persons claiming such machinery under a chattel mortgage or conditional sale where it was shown that the machinery was firmly fixed to the premises so as to become a part of the realty and where the purpose of placing the machinery was to use it in operating the mine.

Arizona Mine Supply Co. *v.* Bloman (Arizona), 140 Pacific, 490, p. 491, May, 1914.

CONTRACTS OF SALE.

SALE OF PHOSPHATE—CONSTRUCTION OF CONTRACT.

A phosphate mining company entered into a contract with a fertilizer manufactory by which the former agreed to sell and the latter to purchase 2,000 tons of phosphate rock at a stipulated price per ton to be shipped by the seller at the rate of 200 tons per week, unless hindered or delayed by either a shortage of cars or the weather, and in the construction of this contract it is to be presumed that the parties were fully aware of the fact that there might be more or less delay in making shipments due to the causes stated, and accordingly it was natural that the seller should take the precaution to insert the proviso that shipments should be made as agreed upon unless prevented by the failure of the railroad company to furnish cars, and as the purchaser acquiesced in this condition it must be concluded that it was the intention of the parties that if the seller was not delayed on account of car shortage the shipments should be made continuously until the entire amount was shipped; but if there should be any delay caused by car shortage or bad weather the seller would be entitled to deliver the rock within a reasonable length of time after the car service had assumed its normal condition; and this proviso as to the shipment must have been intended to relate to the time of delivery and can not be construed to relate to the life of the contract.

Jackson Phosphate Co. *v.* Caraleigh Phosphate & Fertilizer Works, 213 Fed., 743, p. 745, February, 1914.

CONTRACT FOR SALE OF COAL CARS—CONSTRUCTION AND EFFECT.

An agreement between an equipment company and a coal company for the sale of a stated number of secondhand coal cars at a stipulated price per car recited that the agreement was merely tentative and the cars are to be placed upon a trust subject to a car trust agreement, and though tentative can not be set aside by a subsequent detailed agreement substituting a different vendor of the cars and not conforming to the character of the car trust and omitting the provision as to sale through a trustee; and the seller, by thus presenting a proposed different contract, must be regarded as having abandoned the contract as contained in the tentative agreement; and the fact that the corporation owning the secondhand cars from which they were proposed to be purchased would not part with the cars upon any other terms than those expressed in the new agreement does not alter the fact that the contract was substantially different and the proposed purchaser was not bound to execute it.

Cincinnati Equipment Co. *v.* Big Muddy River Consol. Coal Co. (Kentucky), 164 Southwestern, 794, p. 795, March, 1914.

STATUTORY LIENS.

ASSIGNMENT—RIGHTS OF ASSIGNEE.

The owner and holder of a lien for wages against a mining company may sell and assign the same after it has been placed in the hands of an attorney for suit and judgment taken, and the assignee may on demand and notice enforce the same against the attorney of the assignor, and a complaint in a justice's court alleging such facts is sufficient, and the attorney can not escape liability on the ground that he had paid the residue of the claim into the estate of the deceased assignor.

State *v.* Langan (Nevada), 137 Pacific, 517, January, 1914.

MINERS' LIEN—EXTENT.

The statute of Nevada (sec. 2213 R. L.) gives all miners, laborers, and others who work or labor in the amount of $5 or more in or about any mine designed or used for the purpose of prospecting, draining, or working such mine, and all persons furnishing material to the value of $5 or more to be used in or about a mine, whether done or furnished at the instance of the owner of such mine or his agent, a lien upon such mine for the amount and value of the work performed or material furnished; and under this statute a person performing labor or furnishing material for the development of mining property or for facilitating the extraction of ore from a mine is entitled to the lien given by this statute although the labor performed or the material furnished was at the instance of and for the benefit of a lessee of the mining property, operating under a lease to develop the mine, as in such case the lessee is regarded as the agent of the lessor.

Lamb *v.* Goldfield Lucky Boys Min. Co. (Nevada), 138 Pacific, 902, p. 903, February, 1914.

THEORY OF MINERS' LIEN.

The general theory upon which the labor or mechanics' liens is based is that they are remedial and intend to aid the laborer who gives his services or the material man who furnishes his material a security for the value of such services or material, on the principle that the labor performed or the material furnished has enhanced the value of the property and the equitable right is given the laborer to pursue the result of his toil and to the material man to follow his material into the structure of which it became a part; and it is not just that the owner of the property should acquire the benefits of the labor or the improvements accruing from the material without compensating the person furnishing such labor or material; and this rule applies strictly to miners and mining property, though the work may be done for or the material furnished to the lessee of the mine, if the work done or material furnished is done or furnished for the improvement of the property.

Lamb *v.* Goldfield Lucky Boys Min. Co. (Nevada), 138 Pacific, 902, p. 903, February, 1914.

ENFORCEMENT OF LIEN AGAINST LESSOR OF MINE.

By the provision of the statute of Nevada the right of a lien is granted to persons furnishing timber or other materials to be used in or about any mine and also to laborers and others who work or labor in or upon any mine, shaft, tunnel, adit, or other excavation designed for the purpose of prospecting, draining, or working in such mine, and this right to a lien is given whether the work is done or the material is furnished at the instance of the owner of the property or of his agent; and the statute further provides that every contractor, subcontractor, architect, builder, or other person in charge or control of any mining claim or any part thereof shall be held to be the agent of the owner for the purpose of the application of the law; and a lease given by the owner of the mining property to another with the sole object and view of prospecting the property, or of improving the property in the way of determining the existence of ore bodies therein, or for the extraction of ores without any provision for the lessee to acquire benefit from the ore extraction, makes such lessee a contractor working on the property in the interest of the lessor and must be held to be the agent of the owner under the provisions of the statute; but if by the provisions of the lease under which the lessee operates the property the lessor was to derive a stipulated benefit from the ore extraction by the lessee or some share in the net profits derived from the property, then the lease must be regarded as a contract between the parties, the lessee to do the mining work and both the lessee and lessor to share in the proceeds and benefit of the work, and in either case the lessor is the beneficiary of the labor performed in the property and all the material furnished therein, and it is the obvious intent and the manifest spirit of the statute to allow a lien for mining work done upon a mine against the estate or interest therein of the person who is to be benefited thereby.

Lamb *v.* Goldfield Lucky Boys Min. Co. (Nevada), 138 Pacific, 902, p. 905, February, 1914.

NOTE.—The Supreme Court of Colorado and the Supreme Court of Arizona alike have held that the miner is not entitled ordinarily to a lien on the mining property for services rendered or material furnished where the property is operated by a lessee.

Reynolds *v.* Norman (Colorado), 141 Pacific, 466, p. 467, June, 1914.

Milwaukee Gold Min. Co. *v.* Tompkins-Cristy Hardware Co. (Colorado), 141 Pacific, 527, p. 529, June, 1914.

See Wilkins *v.* Abell, 26 Colo., 462, 58 Pacific, 612.

See Griffin *v.* Hurley, 7 Ariz., 399; 65 Pacific, 147.

LIEN FOR LABOR PERFORMED FOR LESSEE—KNOWLEDGE OF LESSOR.

In an action by a laborer to foreclose a lien upon mining property where the complaint alleged that the services were performed at the instance of and for the lessee of a mine acting under a lease executed for the purpose of developing and improving and extracting ore from the property, it must be presumed that the lessor had notice and knowledge that such services were being performed and that laborers were being employed and materials furnished in furtherance of the development and improvement of the property under the terms of the lease.

Lamb *v.* Goldfield Lucky Boys Min. Co. (Nevada), 138 Pacific, 902, p. 904, February, 1914.

LIEN ON LEASED MINE—LIABILITY OF LESSOR.

The owner of a mine who leased it to a third person for operation is ordinarily not liable to a laborer employed by the lessee or to a material man furnishing material to such lessee; but if the lessor knows or has reason to believe that persons performing labor or furnishing materials were relying on him for pay therefor and he remains silent, or if he encouraged the doing of the work or the furnishing of the materials, he then becomes liable on an implied contract.

Reynolds *v.* Norman (Colorado), 141 Pacific, 468, June, 1914.

PROOF TO OBTAIN BENEFITS OF STATUTE.

The provisions of the Colorado statute (sec. 4028 R. S., 1908, and sec. 4583 Mills's A. S. 1912) applying to liens on mining property are governed by the same rules that apply to liens upon other property, and it is necessary for a party invoking the benefits of the statute to prove that at the time the material was furnished there was a mutual understanding between the material man and the contractor that the material was furnished to be used in the construction of a particular building or the improvement of a certain property, or that there was such understanding upon the part of the material man.

Milwaukee Gold Min. Co. *v.* Tompkins-Cristy Hardware Co. (Colorado), 141 Pacific, 527, p. 529, June, 1914.

LIENS ON LEASED MINE—IMPLIED CONSENT OF OWNER.

Section 4584 of Mills's Annotated Statutes of Colorado provides that improvements made upon land with the knowledge of the owner shall be held to have been made at his instance and request, to the extent that the land shall be subject to a lien for such improvements, unless the owner shall, within five days after he shall obtain notice of the same, give notice that his interest shall not be subject to a lien for the same; and a material man seeking to enforce his claim against a mine operated by a lessee under a lease with the owner must aver and prove that the owner had knowledge or notice of the making of the improvements, or that the materials furnished were used in the construction or repair or improvement of his property, and it must always be shown that the materials were furnished to be used in the building or improvement upon the property sought to be charged with the lien, and with the knowledge or understanding that they were to be so used, and credit thereby given to the property into which they were wrought or incorporated, as well as to the purchaser.

Milwaukee Gold Min. Co. *v.* Tompkins-Cristy Hardware Co. (Colorado), 141 Pacific, 527, p. 530, June, 1914.

STATUTORY LIEN FOR LABOR.

The object of the law giving miners a lien on mining property is to secure payment for those who perform labor upon any mining property or who perform labor upon or furnish material in the construction of any building or structure in connection with a mine or mining operations, and a construction or application of the statute should be avoided which sacrifices substance to a mere matter of form, and while there must be a substantial compliance with the essential requisites of the statute the pleadings and notices required by the law should be liberally construed in order that justice may be promoted and the desired object may be effected.

Ferro *v.* Bardo Mining & Milling Co. (Nevada), 140 Pacific, 527, p. 528, April, 1914.

JOINDER OF LIEN FOR DAY AND CONTRACT WORK—ENFORCEMENT.

Where a miner performs labor by the day and where he also runs tunnels or crosscuts or sinks winzes, working at times under a special contract at a stipulated price per foot, the statute gives him a lien on the mining property for such services, but it does not require him to file separate liens for the work done by the day and for the work done under a contract, and in the filing and the enforcement of such a lien he may properly join the work done by the day and the work done under contracts and treat the employment as one continuous transaction; and the courts will treat the employment as one continuous transaction for the purpose of ascertaining the time within which the liens should be filed, and the statute of Nevada does nor prohibit the joining in one lien claim of rights of lien as an original contractor and for labor as an employee where the same person has both such rights or liens and where the character of the work performed was the same and the work was continuous.

Ferro *v.* Bargo Mining & Milling Co. (Nevada), 140 Pacific, 527, p. 528, April, 1914.

DAMAGES FOR INJURIES TO MINERS.

ELEMENTS OF DAMAGES.
DAMAGES EXCESSIVE.
DAMAGES NOT EXCESSIVE.

ELEMENTS OF DAMAGES.

PRESENT WORTH OF EARNINGS.

In an action by a father to recover damages caused by the death of a minor son the plaintiff is entitled to recover the present worth of the probable earnings of the deceased up to the time he would have become of age less the probable cost of clothing and maintenance.

Carnego *v.* Crescent Coal Co. (Iowa), 146 Northwestern, 38, p. 42, March, 1914.

MENTAL ANGUISH.

To sustain a finding and judgment involving damages for mental anguish it is not necessary that direct evidence of such anguish should be produced, but damages for mental suffering may be recovered for injuries where such mental suffering is an element of the physical pain, or is a necessary consequence of the physical pain, or is the natural or proximate result of the physical injury, and such suffering may be inferred as a result from physical pain, and neither courts nor juries can draw a definite or exact line between physical pain and mental suffering.

Baisdrenghien *v.* Missouri, etc., R. Co. (Kansas), 139 Pacific, 428, p. 429.

MEASURE—LOSS TO WIDOW.

Under the statutes of Oklahoma a surviving wife may maintain an action for damages for wrongful death of her husband for the benefit of herself and minor children in the absence of administration on his estate, and in such an action the measure of damages is the pecuniary loss suffered by the widowed wife and children by reason of being deprived of the care, protection, and support of the deceased, to be determined by the age, physical condition, occupation, earning capacity, habits, and the use made by the deceased of his earnings.

Big Jack Min. Co. *v.* Parkinson (Oklahoma), 137 Pacific, 678, p.681, December, 1913.

PROOF OF SUFFERING.

In an action by an injured miner for damages it is proper for witnesses who visited the miner soon after his injury to testify that judging from his general appearance he seemed to be suffering.

Kentucky Midland Coal Co. *v.* Vincent (Kentucky), 166 Southwestern, 800, p. 801, May, 1914.

COMPROMISE PROCURED BY FRAUD—EFFECT.

In an action against a mine operator for damages for injuries to a miner caused by the alleged negligence of the operator a compromise and settlement of the claim procured by fraud is no bar to the prosecution of the case where the sum paid upon the alleged fraudulent compromise is refunded or paid into court.

Interstate Coal Co. *v.* Trivett (Kentucky), 160 Southwestern, 728, p. 730, November, 1913.

Interstate Coal Co. *v.* Trivett (Kentucky), 160 Southwestern, 731, p. 732, November, 1913.

New Bell Jellico Coal Co. *v.* Oxendine (Kentucky), 160 Southwestern, 737, p. 740, November, 1913.

DAMAGES EXCESSIVE.

INSTANCES.

A verdict for $12,000 for injuries sustained by a miner must be regarded as excessive where it appears that the miner was 53 years of age and had been a coal miner for nine years and was injured while being lowered in a cage and by reason of the excessive speed and the negligent failure of the operator to furnish the proper safeguards the miner was thrown upon the bottom of the shaft with such violence as to break his leg, split his knee, and injure his rib, leaving him with a permanently disabled leg, a permanent injury to the rib, and where it appeared that he was earning when hurt $100 per month.

Domineck *v.* Western Coal & Min. Co. (Missouri), 164 Southwestern, 567, March, 1914.

DAMAGES NOT EXCESSIVE.

INSTANCES.

A judgment for $2,000 in favor of a boy under 16 years of age employed in a mine is not excessive where the evidence shows that the ankle and foot were caught between the cars and severely injured; that he was confined to his bed a month; that he went on crutches about the same length of time, and after he disposed of the crutches he was unable to wear a shoe on the injured foot, and that for two years after the injury the foot was stiff and would swell from walking and would remain in such condition for three or four days.

Stearns Coal & Lumber Co. *v.* Tuggle (Kentucky), 161 Southwestern, 1112, p. 1113, January, 1914.

A judgment in favor of an injured miner for $18,000 can not, as a matter of law, be regarded as excessive where the records show that the miner was 29 years old at the time of the accident and was capable of earning $4 a day and his board and lodging and where the miner had been crushed and badly injured.

Johansen *v.* Pioneer Min. Co. (Washington), 137 Pacific, 1019, p. 1023, January, 1914.

In an action for the death of a miner a judgment for $8,000 can not be regarded as excessive where the deceased was 35 years of age, a qualified electrician earning $85 per month, and had an expectancy of over 31 years, and left a widow and five children.

Shirley Coal Co. *v.* Moore (Indiana), 103 Northeastern, 802, p. 804, January, 1914.

Where a miner 43 years of age, healthy and able-bodied, was injured by a fall of rock from the roof, his leg being broken at the ankle so that the bone protruded through the skin and the ankle was badly crushed, the injury difficult to treat and his leg kept in plaster of Paris for three months and the evidence of the attending physician showed that the limb would be permanently injured, that there would always be an enlargement about the ankle, stiffness and weakness at the joint; where he had been engaged in mining for 14 years and earned from $50 to $75 every two weeks, a judgment of $4,500 is not excessive.

Gambino *v.* Manufacturers' Coal & Coke Co. (Missouri Appeals), 164 Southwestern, 264, p. 270, February, 1914.

A verdict for $1,000 for an injury to a miner can not be regarded as excessive where the miner was severely injured by a fall of rock, was on crutches for two months, suffered great pain in various parts of his body, and, though later was able to work, suffered greatly with pain in his ankle and especially so when attempting to walk after resting, and where it is doubtful whether he will ever fully recover.

Jellico Coal Min. Co. *v.* Helton (Kentucky), 163 Southwestern, 744, p. 747, February, 1914.

A verdict of $1,000 for injuries to a miner is not excessive where the injury was caused by the explosion of a pump and a small piece of iron struck the miner just over the eye, where it was sufficient to knock him down and render him unconscious, and where he was confined to his room from three to five days and where his eyesight is affected and he is unable to read for any length of time on account of the injury, and where there is some evidence to show that his mind was affected as a result of the injury.

Stearns Coal & Lumber Co. *v.* Tuggle (Kentucky), 164 Southwestern, 74, p. 75, March, 1914.

Under a statute permitting a recovery of any sum not exceeding $5,000 for the death of an employee, a verdict for $3,500 precludes any contention of passion, prejudice, or undue sympathy on the part of the jury, and can not be regarded as excessive when taken in connection with the age, the exemplary habits, the earning capacity, and the industry of a deceased miner, all of which were shown by the evidence.

National Fuel Co. *v.* Maccia (Colorado), 139 Pacific, 22, p. 24, March, 1914.

A judgment for $250 in favor of a miner injured by a vicious mule, where the evidence showed as a result of the alleged injury that the miner was unconscious when removed from the mine and his injuries were of such a character as to confine him for two weeks or more to his house and to keep him from work, is not excessive.

Gatliff Coal Co. *v.* Wright (Kentucky), 163 Southwestern, 1110, p. 1111, March, 1914.

In an action by a coal miner for injuries from being overcome by black damp in the mine, a judgment for $500 can not be regarded as unsupported by the evidence or as flagrantly against the evidence where the plaintiff testified that as he moved along in the mine he was overcome by the noxious gas and that he then made his way along the entries and in a short time became unconscious, and after he came to he dragged himself to the mine entrance, and that as a result he was weak all summer, could not do any work and could hardly walk, where the report of the mine inspector showed that the air was not in good condition, though the plaintiff's evidence was not supported by any other witness.

Mt. Morgan Coal Co. *v.* Shumate (Kentucky), 163 Southwestern, 1099, p. 1100, March, 1914.

A judgment for $3,000 for injuries to a miner in an action for personal injuries can not be said as a matter of law to be excessive where it was difficult to tell whether it is an injury from which the miner will recover in a few months or he will recover the full use of his foot, the injured part, by the use of mechanical appliances, or whether he will be a cripple for life.

Crooks *v.* Tazewell Coal Co. (Illinois), 105 Northeastern, 132, p. 135, April, 1914.

A verdict for $1,000 can not be regarded as excessive for a miner whose leg was broken and the injured leg by reason of the breaking was rendered shorter than the other.

Big Branch Coal Co. *v.* Sanders (Kentucky), 166 Southwestern, 813, p. 815, May, 1914.

In an action for damages for injuries by a boy 17 years of age who was employed to drive a coal car in a mine a verdict for $850 is not excessive where it appears that the boy was in bed for three weeks as a result of the injury, that he slept very little during the time, and had not been able to do the full labor of a man since, and where it appears that while his leg was not broken the muscles were seriously and permanently injured, and that at the time of the trial the leg was not in its normal condition.

Kentucky Midland Coal Co. *v.* Vincent (Kentucky), 166 Southwestern, 800, p. 801, May, 1914.

QUARRY OPERATIONS.

CONTRIBUTORY NEGLIGENCE—KNOWLEDGE OF DANGER.

An employee in a quarry is chargeable with notice of what is apparent, but not necessarily that the apparent is dangerous, and can be barred of recovery for injuries resulting from perils arising during the course of his employment only when he realizes their nature and extent with full comprehension of the danger and continues in the service with such added exposure voluntarily and intelligently; but the mere fact that such an employee knows the defects does not necessarily charge him with contributory negligence, or the assumption of risks growing out of such defects, but the question is, did he know, or ought he, in the exercise of ordinary common sense and prudence to have known, the risks to which the conditions of the instrumentalities exposed him.

Perreault *v.* Wisconsin Granite Co. (South Dakota), 144 Northwestern, 110, p. 114, September, 1913.

ASSUMPTION OF RISK—CONTRIBUTORY NEGLIGENCE—KNOWLEDGE OF DANGER.

Where the evidence shows that an injury to an employee in a quarry was caused by a danger which ought not to have attended his employment and would not have attended it had the operator performed his whole duty toward the employee, there is no presumption that the employee assumed the unusual risk, and the burden of proof is on the employer to show affirmatively that he did, to the same extent that it is on him to show any other contributory negligence on the part of the employee, as the assumption of an unusual risk in any employment by an employee is in the nature of negligence on his part, which, like any other contributory negligence, prevents his recovery.

Perreault *v.* Wisconsin Granite Co. (South Dakota), 144 Northwestern, 110, p. 113, September, 1914.

See Oiva *v.* Calumet & Hecla Min. Co. (Michigan), 146 Northwestern, 181, March, 1914.

ASSUMPTION OF RISK—BURDEN OF PROOF.

While the law presumes that an employee in a quarry assumed all the ordinary risks incident to his employment, including those connected with the use of proper machinery when properly located, and therefore no proof of assumption of risk in such cases need be pleaded or proved, yet when a risk claimed to have been assumed is out of the ordinary, as when an employer has failed to furnish a reasonably safe place in which his employees shall work, then if the employer seeks to defend an action based upon injury received owing to his own alleged negligence in not furnishing such a proper place and seeks to defend upon the ground that the employee assumed the risk, there being no presumption that such risk was assumed, it then becomes a matter of affirmative defense to be alleged and proved by the employer.

Perreault *v.* Wisconsin Granite Co. (South Dakota), 144 Northwestern, 110, p. 113, September, 1913.

ASSUMPTION OF RISK—INJURY TO WORKMAN.

A person employed as a driller in a stone quarry and whose duty it was to go upon and around the sides of a great pile of pieces of stone varying in size that were thrown upon the pile as they were blasted from the face of the quarry, and who was required to drill holes in the larger pieces of the loose stone in such pile in order that these larger pieces could be broken up so that they could be handled, and where the pieces of stone as piled were sometimes loose and liable to slip and fall or roll down the side of such pile, is not entitled to recover for an injury caused by a mass of stone in the ledge above him breaking loose and rolling down over and upon him to his injury, where it sufficiently appears that the driller himself was as well informed as the operator of the quarry of the likelihood of the stone falling, and where he knew of the constantly changing conditions of the mass of stone, and where it also appears that an inspection by the operator would have been of no consequence to the driller because of the constantly changing conditions, and where the injury arose either from the cause of the changing conditions and work, of which the driller was fully informed, which changing condition of work and of the subject of the work he was employed to assist in producing, or from no known cause.

Lehigh Portland Cement Co. *v.* Bass (Indiana), 103 Northeastern, 483, p. 487, December, 1913.

An employee in a quarry of many years' experience and whose duty among other things was head hooker to hook the hooks or dogs of a traveler used to move stone, and whose duty it was to determine for himself the way and manner in which to move stone in the quarry and in the yard, can not recover for an injury received while in the line of his duty, where he was directed to move a stone, above but not on which was a larger stone, and where without first moving the larger stone he with an assistant put the hooks or dog in the small and underneath stone and himself gave the signal to the engineer operating the traveler, and where in lifting the smaller stone the larger stone was thereby caused to fall on the plaintiff, causing the injuries for which he sued.

Sare *v.* Hoadley Stone Co. (Indiana Appeals), 105 Northeastern, 582, p. 583, June, 1914.

EXERCISE OF REASONABLE CARE—PROOF OF GENERAL PRACTICE.

In an action for damages for the death of an employee in a stone quarry due to the alleged negligent manner in which the operator conducted his quarrying operations, the plaintiff may show the general practice of other employers in similar lines of employment, as tending to show whether the employer has exercised reasonable and ordinary care in providing and maintaining safe appliances and places for work.

Bowles *v.* Virginia Soapstone Co. (Virginia), 80 Southeastern, 799, p. 801, January, 1914.

SAFE PLACE AND APPLIANCES—DEGREE OF LIABILITY.

The operator of a stone quarry, like other employers, is bound to exercise ordinary care in providing safe appliances and places, and the care must be such as reasonable and prudent men use under like circumstances, in providing safe and suitable appliances and instrumentalities for the work to be done and in providing generally for the safety of the employees, regard being had to the work and the difficulties and dangers attending it; but he is not bound to provide the latest inventions nor the most newly discovered appliances, and he is not required to use more than ordinary care, no matter how hazardous the business may be, and ordinary care depends upon the circumstances of the particular case and is such care as a person of ordinary prudence under all the circumstances would exercise, and this must be ascertained by the general usages of the business.

Bowles v. **Virginia Soapstone Co. (Virginia), 80 Southeastern, 799, p. 801, January, 1914.**

EMPLOYER NOT AN INSURER OF SAFETY OF EMPLOYEES.

The operator of a stone quarry is not held to any higher degree of skill than the fair average person of his profession or trade, and he is not an insurer of the safety of his employees and is liable for the consequences not of danger but of negligence.

Bowles v. **Virginia Soapstone Co. (Virginia), 80 Southeastern, 799, p. 801, January, 1914.**

DANGERS IN SOAPSTONE QUARRY.

The quarrying of soapstone is necessarily hazardous and the elements of danger can not be wholly eliminated, and such a quarry can not be conducted without blasting and the use of machinery which causes vibrations, and the operator of such a quarry can not be held liable for an injury to or the death of an employee from the fall of a rock, on the ground of alleged negligence in keeping the walls so perpendicular that loosened stones would be liable to fall from the jar incident to the work, where the proof showed that the wall for some 60 feet was almost perpendicular and the discovery of a seam no thicker than a knife blade, and where the quarrying was carried down to a considerable distance and after some 3 or 4 yards another seam of the same character of the first was discovered, and where iron pins were introduced along the lower edge of the seam, and during all of the time frequent and careful inspections were made of the face of the wall by sounding with heavy hammers and crowbars and there was no evidence of the slightest character of any movement of the stone, and no discovery of anything to indicate that any movement was to be apprehended, except the seams mentioned, and where the quarrying continued for a year after the discovery of the second seam without indications of danger, when suddenly and without warning a great mass of stone fell and caused the death complained of.

Bowles v. **Virginia Soapstone Co. (Virginia), 80 Southeastern, 799, p. 802, January, 1914.**

EVIDENCE OF SUBSEQUENT REPAIRS INADMISSIBLE.

In an action for the death of an employee in a quarry caused by a fall of rock due to the alleged negligence of the operator in failing to properly inspect and make safe the wall of the quarry, evidence is not admissible to show that the inspection of the walls of the quarry was more frequent after the accident than before, and that the operator subsequent to the accident put more pins in the wall for the purpose of making it safe.

Bowles *v.* Virginia Soapstone Co. (Virginia), 80 Southeastern, 799, p. 800, January, 1914.

NOISES—NUISANCE.

The owner and operator of a granite quarry may be enjoined from operating surfacing machines, though necessary in the process of the development of the granite industry and necessary for the successful prosecution of the particular quarry, where by reason of being operated by compressed air the surface machines produce a loud, penetrating, confused, and disagreeable noise that interferes with the reasonable comfort and enjoyment of life to the inhabitants of the particular locality used principally for residences.

Stevens *v.* Rockport Granite Co. (Massachusetts), 104 Northeastern, 371, p. 373, February, 1914.

LEASE OF LANDS AND QUARRY—GRANT OF RIGHT OF WAY—CONSTRUCTION.

The owner of a stone quarry leased the same for a term of 25 years, and at the same time and by the same instrument granted to the lessee the right to construct and maintain a switch over other lands of the lessor by which lessee should quarry and remove stone by means of such switch and to connect the stone quarry with a nearby railroad, and the lessee reserving the right, on the termination of the lease, to remove all buildings, sidetracks, switches, and property of every kind from said premises; and the fact that the lessor subsequently conveyed the land over which the switch was laid and maintained, on the termination of the lease, and leased the quarry to other persons, did not in anywise affect the rights of the lessee and did not extend the time or make permanent the easement to maintain the switch, but the original lessee on the termination of the lease had the right to remove the buildings on the leased premises, including the switch, and the easement for the maintenance of the switch terminated at the end of the 25-year period.

Spencer Stone Co. *v.* Sedwick (Indiana Appeals), 105 Northeastern, 525, p. 527, June, 1914.

PATENT FOR STONE LAND—FRAUD—CANCELLATION.

Patents issued under the timber and stone act may be set aside and canceled for fraud on the part of the patentee in conspiring to purchase entries pursuant to a prior agreement on the part of the entryman to transfer the title to persons not bona fide purchasers for value.

United States *v.* Kettenbach, 208 Fed., 209, p. 214, October, 1913.

WATER RIGHTS.

CONSTRUCTION OF STATUTE.

Congress evidently perceived that the time had come when the changed conditions and the complex interests and relations of the national life demanded a change in the rules relating to water rights on the public domain in the arid regions of the Western States, as applied under the original act of July 26, 1866 (14 Stat., 251, sec. 9), and as embodied in section 2339 of the Revised Statutes of the United States, and accordingly modified that act by the subsequent legislation as seen in the acts of March 3, 1891 (26 Stat., 1095), February 4, 1911 (36 Stat., 1235, p. 1253).

United States *v.* Utah Power & Light Co., 209 Fed., 554, p. 561.
Reversing United States *v.* Utah Power & Light Co., 208 Fed., 821, p. 823, November, 1913.

The acts of May 14, 1896 (29 Stat., 120), and of March 4, 1911 (36 Stat., 1235, p. 1253), authorizing the Secretary of the Interior and other public officers to grant rights of way and the use of ground on the public domain to electric power companies, modify and limit, at least as to such companies, the general provisions of section 2339 of the Revised Statutes of the United States; and while these later acts can not deprive corporations or persons of vested water rights for mining and domestic purposes, corporations can not acquire rights of way over the public domain to be used in generating electric power under the original section 2339, but a right of way for such purposes can be granted under the later acts by the Secretary of the Interior only.

United States *v.* Utah Power & Light Co., 209 Fed., 554, p. 561, November, 1913.
Reversing United States *v.* Utah Power & Light Co., 208, Fed., 821, p. 823.

VESTED RIGHTS PROTECTED—PURPOSE OF STATUTE.

The purpose of section 2339 of the Revised Statutes of the United States was to confirm title to possession acquired under forms and regulations sanctioned by the State and molded by its courts, with the acquiescence and tacit encouragement on the part of the Government; and the section was a voluntary recognition of the preexisting right of possession, constituting a valid right of claim to its continued use, rather than the establishment of a new right.

United States *v.* Utah Power & Light Co., 209 Fed., 554, p. 560, November, 1913.

APPROPRIATION NECESSARY FOR USE ON MINING CLAIM.

The locator of a lode mining claim is not entitled to the use of water flowing from a spring in a natural channel without making a proper appropriation of the same to a beneficial use, and in the absence of such an appropriation a third person may by proper appropriation acquire a vested interest in the use of such water.

Campbell *v.* Goldfield Consol. Water Co. (Nevada), 136 Pacific, 976, p. 978, December, 1913.

WATER RIGHTS—CUSTOMS.

The effect of a custom prevailing in an Alaska mining district by which an entry upon unpatented mining claims was permitted to one seeking to appropriate water flowing through such unpatented claim, becomes wholly immaterial where the mining claim was held to be invalid because of the failure to prove discovery.

Ebner Gold Min. Co. *v.* Alaska-Juneau Min. Co., 210 Fed., 599, p. 604, January, 1914.

VESTED RIGHTS FOR MINING PURPOSES.

Where vested water rights for mining purposes have accrued under section 2339 of the Revised Statutes of the United States, and such rights are recognized and acknowledged by local customs, laws, and decisions of the courts, such rights are protected by the statute and can not be forfeited or otherwise lost by any acts of the Government officers.

United States *v.* Utah Power & Light Co., 208 Fed., 821, p. 822, March, 1913.

RIGHT OF WAY PROTECTED.

A power company obtaining a right of way for a pipe line to conduct water to its plant and mine for mining purposes will be protected in its right to the continued use of such right of way and pipe line where the land is subsequently incorporated in a forest reserve.

United States *v.* Utah Power & Light Co., 208 Fed., 821, p. 823, March, 1913.

PUBLICATIONS ON METHODS OF MINING.

Limited editions of the following Bureau of Mines publications are temporarily available for free distribution. Requests for all publications can not be granted, and applicants should select only those publications that are of especial interest to them. All requests for publications should be addressed to the Director, Bureau of Mines, Washington, D. C.

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Bulletin 91

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
BUREAU OF MINES
VAN. H. MANNING, DIRECTOR

INSTRUMENTS FOR RECORDING CARBON DIOXIDE IN FLUE GASES

BY

J. F. BARKLEY AND S. B. FLAGG

WASHINGTON
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INSTRUMENTS FOR RECORDING CARBON DIOXIDE IN FLUE GASES.

By J. F. Barkley and S. B. Flagg.

INTRODUCTION.

In the past few years an awakened activity in power-plant economies has resulted in a marked improvement in the equipment for generating and utilizing steam. Although the improvement in design and construction of steam-driven prime movers has been greater than that of the steam-generating equipment, the economies obtained with the more efficient engines and turbines have stimulated interest and activity in eliminating unnecessary boiler and furnace losses.

Much attention has been given to the boiler room in efforts to obtain proper combustion of the coal, because of the importance of the coal item in costs of power production. As evidence of this increasing interest may be cited the record of the development within the past few years of new apparatus for the analysis of flue gases. Many new forms of apparatus have appeared, including those for the determination of carbon dioxide, oxygen, and carbon monoxide, and others for indicating and for recording the content of carbon dioxide only, as carbon dioxide content is usually a good indicator for the control of furnace operation.

Because of the large number of steam-power plants operated by the Federal Government and the number of CO_2 recorders used therein the Bureau of Mines undertook to collect information regarding the practical application of such recorders. Articles published from time to time concerning CO_2 recorders have been mostly descriptive, giving little reliable information as to the results that could be expected from the various types of instruments in ordinary practice, and most of the tests made have been of a laboratory nature.

Tests of several different types of recorders were made under service and laboratory conditions in order to obtain needed information. The purpose of the Bureau of Mines in publishing the results is to show the factors which may affect the accuracy of a CO_2 recorder and the manner in which a recorder should be tested. Readers should note that the remarks on different recorders apply to the instruments tested and not to later instruments of the same makers.

In the course of the tests the following details were determined:

1. The lag in recording changes of composition of a flowing gas.
2. The accuracy of each type of recorder.

3. The variable factors affecting the operation and accuracy of each type.
4. The repairs and renewals necessary.
5. The kind and amount of attention required.

To acquire data relative to the first three items special tests of a laboratory nature were conducted, whereas the information relative to items 4 and 5 was obtained by operating the instruments for a period of several months under conditions practically the same as would be met in a commercial steam-power plant having only a day load. In connection with this work some experiments were made to ascertain the effect of minor changes in the installation and the operation of the instruments. The instruments were numbered consecutively, the number assigned to each instrument being noted below. Throughout this report the instruments are, for convenience, designated by number. The CO_2 recording instruments tested were as follows:

1. The bimeter CO_2 recorder, made by the Cambridge Scientific Instrument Co., Cambridge, England.
2. The Simmance-Abady CO_2 recorder, made by the Precision Instrument Co., Detroit, Mich.
3. The "Sarco" automatic combustion (CO_2) recorder, Sarco Engineering Co., New York, American representative.
4. The "Telezometer" CO_2 recorder, made by G. A. Schultze, Berlin-Charlottenburg, Germany.
5. The Uehling CO_2 machine, made by the Uehling Instrument Co., Passaic, N. J.

The indicating instruments tested were as follows:

6. The CO_2 thermoscope, made by the Underfeed Stoker Co., London, E. C.
7. Dr. A. Schmid's pocket CO_2 indicator, made by J. G. Cramer, Zurich, Switzerland.

The makers of the instruments mentioned each consented to having the Bureau of Mines make the tests outlined, with the understanding that the results would be published.

ACKNOWLEDGMENTS.

The authors wish to express their appreciation of the interest shown by the Precision Instrument Co., the Sarco Engineering Co., and the Uehling Instrument Co., and by Herman Bacharach, of Pittsburgh, Pa., representative of J. G. Cramer and G. A. Schultze, who loaned their instruments for the tests and assisted in every way possible. The authors are also indebted to F. K. Ovitz, assistant chemist, and L. L. Satler, jr., junior chemist, of the Bureau of Mines, for their cooperation.

DESCRIPTIONS OF INSTRUMENTS AND INSTRUCTIONS FOR THEIR INSTALLATION AND OPERATION.

BIMETER CO_2 RECORDER. INSTRUMENT 1.

DESCRIPTION.

Figure 1 shows the internal parts and connections of the bimeter CO_2 recorder. The apparatus consists of two gas meters m_1 and m_2, an absorption box *e*, a water-jet suction pump *b*, and a recording mechanism *f*, *g*. The water-jet suction pump or aspirator *b*, with a consumption of about 2¼ gallons per hour, draws about 1½ cubic feet of the flue gas through the instrument per hour. The gas entering at *d* is cooled in the first chamber of the cooler *k*, and then measured in meter m_1. The CO_2 is then extracted from the gas in the absorption chamber *e* containing lime. As, during this chemical process, the remainder of the gas becomes heated, it is again cooled to its former temperature by being passed through a second chamber of the cooler *k*. From the cooler the gas is led to the second meter m_2 to be again measured, and is thence allowed to escape to the atmosphere by way of the aspirator *b* and the water vessel *c*.

The water used in the operation of the instrument enters at the cock *a* and flows through the cooler *k* into the aspirator *b*. It there draws in the flue gas, and the mixture of water and gas passes into the water vessel *c*. From this the water escapes through an overflow drain pipe *h* and the gas bubbles into the atmosphere.

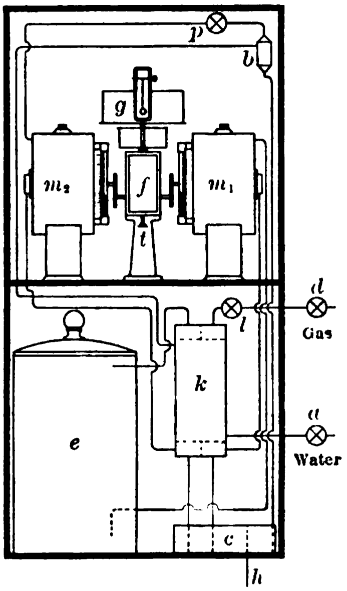

FIGURE 1.—Internal parts and connections of bimeter CO_2 recorder.

The two gas meters are filled with oil, and are so arranged that when no absorption takes place the meter m_2 runs about 4 per cent slower than the meter m_1. Thus, when no CO_2 is absorbed, the recording pen is made to record lines about 3 or 4 mm. in height. The actual height of these zero marks is immaterial so long as they terminate at the zero line of the chart.

This recording pen is actuated by means of a differential drive *f*, operated by the two meters. On an average 20 to 25 analyses may be recorded per hour, the number being dependent on the volume of the flue gases passing through the instrument. The number may be regulated by adjustment of a throttle *p*, placed in the gas passage near the aspirator *b*. If throttle *p* becomes clogged it can frequently be cleaned by closing it entirely, then reopening.

Figure 15 shows instrument 1 installed for tests.

INSTRUCTIONS FOR SETTING UP INSTRUMENT.

The filter for instrument 1 is placed as close as possible to the sampling tube at the beginning of the gas line. The upper part of the soot filter is filled with wood shavings and excelsior, as shown in figure 2, or excelsior can be used entirely. The filter contents should not be packed tightly. The filled upper part is placed in the lower part, which is filled with water so as to form a water seal. In order that the water may not evaporate a little oil is poured on its surface.

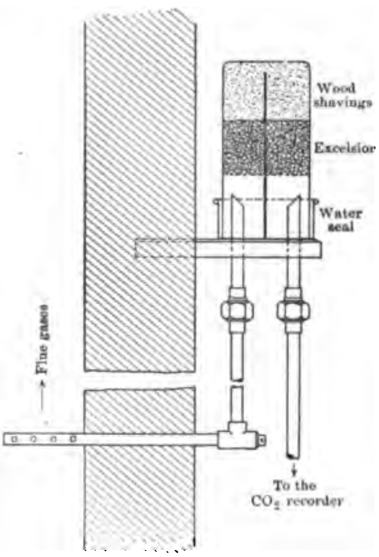

FIGURE 2.—Soot filter and connections, bimeter CO$_2$ recorder.

The recorder should be suspended vertically on hooks or screws fixed at a height of about 4½ feet above the floor. The water tank supplied is then fixed vertically above the recorder by means of screws set into the wall at a height of about 21 inches above the recorder supports. The iron tube supplied should next be screwed to connect the water tank to the water cock fixed to the recorder connection *a* (fig. 1).

The water necessary for operating the apparatus may be taken from the ordinary house supply or from a reservoir by means of a half-inch pipe. A float valve in the water tank controls the supply of the water, but the insertion of a stopcock immediately in front of the tank is recommended. If the water contains impurities filtration may be necessary. It is well to attach to the water line a vertical drain pipe with cock in such a manner as to permit draining of the instrument each time before it is started. Such drainage tends to prevent the accumulation of dirt in pockets. The gas connection at *d* (fig. 1) is made by a half-inch gas pipe from the main gas line to the recorder.

The gas meters m_1 and m_2 are now filled with the oil supplied. Cock *l* is opened to the atmosphere, and the plugs at the top of both meters are also opened, the gas and water cocks *d* and *a* being closed. The oil is poured into the meters by means of a bent funnel supplied for this purpose, and the position of the oil is correctly set on the zeros of the scales. The meter drums are once slowly rotated by hand in order to get rid of the air bubbles in the corners; and if necessary the position of the oil is corrected. The plugs on the meters are then replaced tightly. The final adjustment of the quantity of oil is made according to the "zero adjustment" explained in a subsequent paragraph.

PREPARATION OF LIME FOR ABSORPTION CHAMBER.

In preparing the lime for the absorption chamber, about 1 hundredweight of burned marble lime or good white lime is slaked in the following manner. After the larger pieces of lime have been broken they are placed in a basket and dipped for about half a minute in water. The resulting mass is then emptied into a flat box and covered over. After an interval of a few hours, examination is made to determine whether the lime has become pulverized; if not, the lime is sprayed with a small quantity of water and covered again. This process should be repeated until the mass falls into a powder. If lime that is already slaked is available, it can be used directly.

FILLING THE ABSORPTION CHAMBER.

The absorption chamber is filled with a mixture of excelsior and lime. The filling requires care and should be done by the same person each time renewal is necessary, in order to obtain uniform service from each chamber or jar. The excelsior is made thoroughly damp and a thin layer, less than one-half inch in thickness, is placed in the bottom of the jar rather loosely. Lime is scattered over this, then more excelsior added, and so on. The object, however, is not to have the two materials in layers but to have a jar full of a loose mixture of excelsior and lime. If, when the chamber is about full, it is pounded lightly on the table, the mixture will settle about as desired. Another thin layer of excelsior is put on top after the mixture has filled the jar. Before the cover is reclamped the rubber packing ring should be well cleaned and greased with a little vaseline. It is important to tighten the cover clamping screws as symmetrically as possible.

TEST FOR AIR LEAKS.

The chamber is connected in position and a test is made to insure that there are no air leaks. The gas cock *d* is closed and the air cock *l* is opened. The water tap *a* is then opened and the oil observed in the oil gages of the meters. The right-hand, or m_1, gage should read very near zero; the left-hand gage should not fall much lower than 25. It may read higher. Should it fall lower the absorption chamber has been packed too tightly and, owing to the formation of water in the jar through the chemical action between the lime and the CO_2, this draft may increase from day to day until the oil level drops out of sight. The air cock *l* is now closed, the oil in the gages is allowed to fall about 30 mm., and the water tap is then closed. The gages come to rest somewhere in sight; if the apparatus is gas tight the oil levels will not change. If the levels rise perceptibly in a short time, there is a leakage to be traced, probably in some of the joints. This test for air leaks should be made whenever a new jar is placed in service.

Similarly, immediately after erection of the instrument the whole of the gas-pipe connection to the filter can be tested. The upper part of the soot filter should be removed and the pipe connecting to the flue should temporarily be plugged so as to make it air-tight. With the air cock *l* closed and the gas tap *d* open, the leakage test is again made.

ADJUSTMENT OF INSTRUMENT.

The instrument is now ready to be adjusted. The knurled screw at the top of the recording drum should be tightened by turning it clockwise. The drum should then be turned counterclockwise, thus winding the clock. As soon as the clock has been fully wound the knurled screw automatically loosens itself. The chart may now be set on the drum, care being taken that the bottom edge of the chart rests on the flange of the drum. When the pen points to the correct time on the chart the knurled head is screwed up. With the gas cock *d* closed and the air cock *l* open, the recorder is set in operation by opening the water cock *a*. The flow should cause large gas or air bubbles to appear without interruption in the water vessel *c*. In this condition the apparatus absorbs no CO_2 but records the slight difference in the speed of the two meters. This difference depends on the position of the air surfaces in the two meters, and is correct when the record lines on the chart are no longer than the free space below the zero line, or about 4 mm. If the marks are longer, a small quantity of oil must be added in meter m_2, or some taken from m_1; if, on the other hand, the lines are very short, they will be lengthened if a small quantity of oil is taken out of meter m_2 or added to meter m_1.

For running oil out of the meter, the small cocks fitted to the bottom of the meters are unscrewed. After the length of the lines has been so adjusted, the position of the recording pen is corrected by means of the adjusting screw *t*, in order that the upper ends of the record lines may average on the zero line of the chart. The recorder should be operated for about one hour. The gas cock *d* may then be opened and the air cock *l* closed. The recorder will now register the CO_2 content.

Throwing back the small lever at the right-hand side of the differential gear box *f* puts the recording pen out of gear. The pen should always be thrown out of gear when the instrument is not in use. From time to time the quantity of oil in both meters should be noted. The level in the right-hand gage will show the draft on the gas line.

SIMMANCE-ABADY CO$_2$ RECORDER. INSTRUMENT 2.

CYCLE OF OPERATIONS.

The Simmance-Abady CO$_2$ recorder is shown in figure 3. A presentation of the cycle of operations will explain its construction and the principles of its action.

The cycle of operations is as follows, the letters ascribed to parts referring to figure 3. Water from the reservoir *k*, having safety overflow *oo*, flows through the hollow valve stem *e*. In siphon tank *a* there is the weighted float *b*, which is attached by means of the chain *c* to the bell *d* of the extractor; the float rises with the water, allowing the bell *d* to fall. At the top of its stroke the float *b* raises the valve stem *e*, thus tripping the valve, and momentarily flushing the siphon tank; the water now siphons out of *a* through siphon tube *g*, allowing the weighted float *b* to fall. As it falls it draws up the water-sealed extractor bell *d*, in which is created a partial vacuum, and into which, therefore, gas flows from the flue through *p* and *h*.

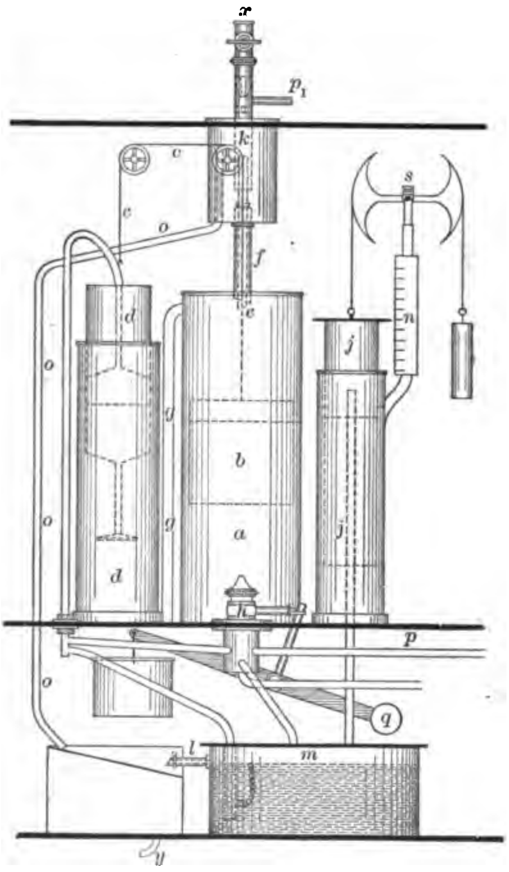

FIGURE 3.—Simmance-Abady CO$_2$ recorder.

Next, the weight of the water that has flowed from the siphon tube *g* into the small pot beneath it overcomes the weight of the counter *q* and closes the balance valve *h*, thereby cutting off a definite sample of the gas. Water is released from the small pot in time to allow the valve to open at the proper interval. The stream of water is continually flowing into the tank *a*, and the float *b* rises again, allowing the extractor bell *d* to sink. As it sinks, the gas in bell *d*, which, by the closing of valve *h* is now uninfluenced by vacuum or other conditions in the flue, is first reduced to atmospheric pressure, and is then under further pressure. The volume of gas is, therefore, forced into the caustic potash vessel *m*, where it bubbles up through the caustic potash and its CO_2 is absorbed; thence it passes into the recorder *j*, raising the bell.

The boxwood scale *n* at the side of the recorder tank is graduated to show 100 per cent CO_2 at the bottom and 0 per cent CO_2 at the top, and the capacity of the bell *d* is such that when the apparatus is run on air, containing practically no CO_2, the total volume is transferred to the recorder bell *j*, which then rises to the zero point. When flue gas is admitted to the apparatus, exactly the same quantity, that is, enough to send the recorder bell up from 100 to 0, is passed from the extractor bell *d*, but on the passage of the gas, the CO_2 is absorbed by the caustic potash in the steel vessel *m*, reducing the volume of the gas; owing to such absorption the recorder bell *j* will not rise to its full height. It will rise automatically to some point, and the pen will drop, registering its position on the chart.

The bell *j* then vents, discharging the analyzed gas through the balance valve *h* so that it does not mix with or come in contact with the fresh charge of gas, which is dealt with in exactly the same way, the whole operation, as well as the continuous drawing forward of the flue gas, taking place automatically by means of the stream of water. For the purpose of introducing a constant supply of gas, there is, below cock *x*, the injector or aspirator attached to the top of the case; p_1 is an auxiliary gas connection to the aspirator from the main inlet pipe *p*. By this means gas is continuously exhausted from the pipes connecting the recorder to the boilers.

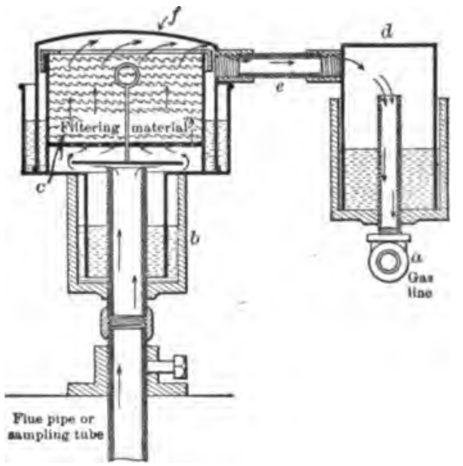

FIGURE 4.—Dust filter and connections, Simmance-Abady CO_2 recorder.

Figures 15 and 16 show instrument 2 as installed for tests.

PLACING OF THE INSTRUMENT.

To avoid vibration the recorder should be placed upon a firm foundation, either a brick pier, about 24 inches wide by 20 inches deep by 30 inches high, or steel brackets attached to the wall. If the recorder is to take samples from a battery of boilers, it should preferably be placed about midway between the extreme ends of the battery, so as to shorten the maximum distance of travel of the gases. The distance between the recorder and the farthest sampling pipe should not exceed 200 feet. The place selected should be as free from temperature changes as possible.

DUST FILTER.

Figure 4 shows the filtering arrangement. A dust filter, *c*, with a cover, *f*, is provided. The filter cover and the cap *d* are connected by a length of gas pipe or armored hose, *e*. The filter *c* is set into the cup *b*, and light oil is poured into the channel in the filter in which the filter cover rests. The oil acts as a seal. The filter is then filled with filtering material (excelsior, cotton waste, etc.), not packed too tightly, and over this is placed a piece of light flannel which is held in place by a cast-iron ring. The filter cover is then placed on and sealed with oil. Only enough oil is used to make the seal and keep the connection air-tight. The level of the oil in the cups will be depressed by the vacuum in the flues, and if additional oil is poured in at this juncture, the oil is likely to flood the line. The gas passes through filter *c* and connection *e* to cap *d*, and thence to gas line *a*.

GAS AND WATER CONNECTIONS.

The gas line is brought down to the instrument, and connection is made at *p* (fig. 5) by a rubber tube *c*. Bottles *a* and *b* are telltales to show respectively whether the flue-gas pipe is clear of obstructions and whether a constant stream of gas is maintained. Each bottle is fitted with a rubber stopper, through which extends a long and a short glass tube. The longer tube is sealed in bottle *a* with about 2 inches of water or light oil and in *b* with about one-half inch. Water in *b* should bubble constantly and smartly to show that the gas is passing freely and that the injector is working; water in bottle *a* should bubble only when the gas piping becomes stopped, when the safety seal opens and air passes into the extractor bell through the longer tube. Figure 5 shows the exact arrangement of bottles that should be made. It is essential that there be no leak at the rubber stoppers.

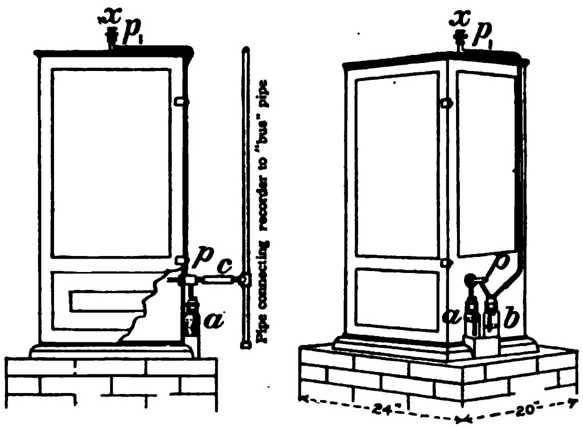

FIGURE 5.—Recorder case and gas and water connections, Simmance-Abady CO_2 recorder.

The water that operates the recorder should be supplied under a constant head and should be clean. The water may be passed under city pressure through a water filter, which can be made of a length of gas pipe, placed vertically for ease of cleaning, with blank flanges at both ends, the bottom half of the piping being filled with coke and the upper half with sand, and the top covered by a piece of flannel. Such a filter is necessary only for very dirty water; for ordinary water a small filter is supplied. The water from the filter flows to a tank having a float valve, which may be an ordinary water-closet tank, and thence under constant head to the recorder.

The constant-level tank should be covered with a piece of canvas or a board so as to prevent dirt from falling in. Such dirt would obstruct the free passage of water and would in time get into the injector at the top of the recorder. The tank should be at least 6 feet above the recorder. The pipe through which the water flows from the tank to the recorder is quarter-inch wrought-iron pipe, which is screwed into the female end of the cock *x* (fig. 3) at the water inlet just above the filter pump on top of the apparatus. The water pipe should not be run near hot steam pipes, as hot water will raise the temperature inside the case of the recorder; the result would be to make the recorder sweat and cause the water to evaporate rapidly in the extractor and recorder tanks. A quarter-inch drain pipe for waste water is run to the sewer from the connection at the bottom of the case.

PREPARATION AND USE OF CAUSTIC POTASH SOLUTION.

After the recorder has been removed from the packing case and placed in position the first operation is to make the caustic solution and allow it to cool. The solution should be caustic potash (KOH), not caustic soda (NaOH), and is made by emptying the contents of one 2-pound KOH tin into the tin-lipped vessel provided and filling carefully with clean water up to the wire gage inside the vessel. When the solution has been allowed to cool to room temperature it should be placed in the steel KOH tank and stirred well to dissolve the caustic. More KOH can be used, and the solution will last much longer; the specific gravity may be 1.27. A small glass funnel is provided with which the KOH solution can be poured through rubber tubing into the center nipple of the cylindrical steel tank *m* (fig. 3), the pinch cock on the overflow tube *l* being kept open. If the tank is standing on a level table, the excess will obviously run out through the overflow tube, thus giving an absolute level. The pinch cock should be closed carefully so that tank will be air-tight. The caustic potash solution is corrosive, and it should not be allowed to come in contact with the hands or clothes nor any part of the apparatus other than the vessel *m*. The shelf of the recorder should be level.

SETTING UP THE RECORDER.

Figure 3 shows clearly the position of the various parts. Directions for assembling the parts are as follows: Screw the filter pump containing injector into the threaded connection inside the overflow tank *k* as far as the thread will allow or until the lower end of the filter pump is submerged. Fill tanks *d* and *j* with clean water to overflow, placing wide-mouth bottle under overflow pipes.

. Run some water into siphon tank *a* and drop float *b* into siphon tank. Connect chain on float to small gold-plated chain *c* and run over pulleys to hook on extractor bell *d*.

Hang balance arm *s* on its fine-point bearings in the grooved cradle, being careful that the weighted adjusting arm extends to the right. Attach fine chain from segment of balance arm to hook on recorder bell *j*; then hang brass counterweight on opposite end of balance arm.

Attach striker lever *q* with bucket to pin under shelf so that the upright arm on the striker lever will engage yoke on lever of cock *h*. Note that yoke does not strike siphon tank and that *q* does not strike nut attaching recorder tank to shelf.

Make rubber connections as shown in figure 3, being careful that there are no kinks in the rubber tubing. If the rubber becomes worn or seems loose, paint with asphaltum paint.

Vaseline is thinly smeared on the ground face of the balance valve *h*. Lubrication once a week is generally sufficient. The ports in the valve and its socket should not be obstructed with vaseline, as this will hinder the passage of the gas.

Now place a chart on the clock disk, being sure that the center point on the disk passes through the center of the chart. It may be necessary to punch a hole with a pin in the center of the chart before placing the chart. The clock and pen levers are now placed in position. The pen fittings consist of two distinct sets of parts, first the pen proper with its brass arm and screw counterbalance weight, and, second, the black bronzed actuating lever with its weight suspended by a chain. The screw counterbalance weight of the pen is adjusted so that the end fitted with the hanging weight is slightly the heavier, and so that when the support of the actuating lever is withdrawn the hanging weight is free to descend until it touches the disk of the recorder bell; when in position the weight is held up and kept there by the projecting end of the black actuating lever, which, when in its socket, is about at right angles to the pen arm. The black arm with weight suspended by chain is fitted in the pillar, which is over the back or siphon tank *a*, so that the weight hangs over the tank, and can thus be lifted by the rising of the float *b* in the tank, and the pen arm released. The pen thus descends at the last moment of the stroke of the analyzer bell, so as to allow for the dispersion of the heat generated by the combination of the CO_2 with the KOH. Put the pen on its fine points into the grooved cradle provided, and see that the black arm mentioned is under the pen arm and supporting it.

The pen arm should be of such a length that the pen point will swing over the exact center of the chart. When the pen is at rest see that the levers rest lightly on the ends of the adjusting screws, and that there is no play between the ends of these screws and the lever arms, the pen movement being held rigidly in place. This adjustment becomes at once apparent when the pen mechanism is hung in place. See that the point of the pen on this rest position stands about three-sixteenths to one-fourth inch to the right of or below the zero line; that is, about −2 per cent on the chart. The adjusting screws can be lowered or raised to make this adjustment.

FINAL ADJUSTMENT OF INSTRUMENT.

The final adjustment of the instrument can now be made. The water is turned on with such a pressure that the machine records its maximum number of records per hour—about 16 or 17. Greater pressure will prevent the siphon from stopping, and the cycle will never be made. As all connections have been made, the instrument will now be running on the flue gas. The first stroke will create the proper levels in the tanks, the excess flowing in the bottles provided. Note the temperature and the draft as recorded in the telltale bottle. This draft will represent the average draft, and the temperature should be an average one. Bell jar *j* (fig. 3) will be rising to some point on the boxwood scale, but not up to the zero mark.

See that the pen point registers on the chart the exact point where the edge of the jar is registering on the boxwood scale. Adjust entirely by means of the small brass nut that strikes the jar. Stop the instrument, if necessary, at the point in the cycle when the pen is registering so that it can be ascertained that the jar and pen are registering the same at any moment when the striker rod is resting on the jar. Disconnect rubber joint *c* (fig. 5), throwing the instrument on air. While the instrument is running, by means of an adjustable pinchcock, slowly close *c* until the telltale bottle shows the same draft as when running on flue gas. The pen (and jar) should register zero at the end of each analysis. If not, adjust by means of the weighted adjusting arm on balance arm *s* (fig. 3). Twisting away from the fulcrum will cause the jar to rise higher.

After all adjustments have been made, operate the instrument for about 30 minutes, being careful to see that the telltale bottle registers the proper draft, which may require careful adjustment. Next, remove the pinchcock from the connection *c* (fig. 5). The telltale bottle will now show no draft. Operate for another 30 minutes and note where the pen registers. It will be somewhere below zero, depending on the amount of original draft. Afterwards, to check the zero point the instrument can be thrown on air at no draft and made to register this minus point as found. It is well to check this point every few days and particularly when there is much temperature change. The instrument can now be thrown on the flue gas for continuous running.

MISCELLANEOUS INSTRUCTIONS.

Wind the clock every week. It runs for eight days. Do not overwind. The clock is regulated before being sent out, and can be kept in adjustment by the regulator in the usual manner.

Every morning fill up the tanks with water to make up for evaporation, allowing the excess to flow out as before. In a later type, an automatic arrangement for keeping these levels constant is in use. Unless a maximum of two drops per cycle and exactly the same amount of water per cycle can be made to flow by the adjustment valve, the other method would better be used, as this flow affects the reading.

Every morning open pinchcock *l* (fig. 3) to keep the KOH level constant, as water forms from the chemical action involved, raising the level continually.

If the chart curls, leave the doors open slightly. Watch the condition of the joint of the cover on the KOH tank, which may leak. This will cause the instrument to read high.

"SARCO" AUTOMATIC COMBUSTION (CO_2) RECORDER. INSTRUMENT 3.

DESCRIPTION OF OPERATION OF INSTRUMENT.

For the "Sarco" automatic combustion (CO_2) recorder the power required is derived from a fine stream of water at a head of about 2 feet. The water enters the instrument at *8* (fig. 6) through the small glass injector *9*. Of the latter several are provided, having apertures of different sizes, and by using different sizes the speed of the machine may be adjusted at will.

The water flows through tube *74* into the power vessel *82;* here it compresses the air above the water level, and the pressure is transmitted to vessel *87* through tube *78*. The pressure thus brought to bear on the surface of the liquid with which vessel *87* is filled to mark *95* sends the liquid upward through tubes *91* and *93*.

Thence it passes up into vessels *77*, *66*, *68*, and *67*, and into tubes *51*, *52*, and *49*. It rises until it reaches the zero mark *71*, on the narrow neck of vessel *67*. At the moment it reaches this mark the power water, which, simultaneously with rising in vessel *74*, has also traveled upward in siphon *72*, will have reached the top of this siphon, which then begins to operate.

Through siphon *72* a much larger quantity of water is disposed of than flows in through injector *9*, so that the power vessels *74* and *82* are rapidly emptied.

The moment the pressure on vessel *87* is thus released, the liquids return from their respective tubes into this vessel.

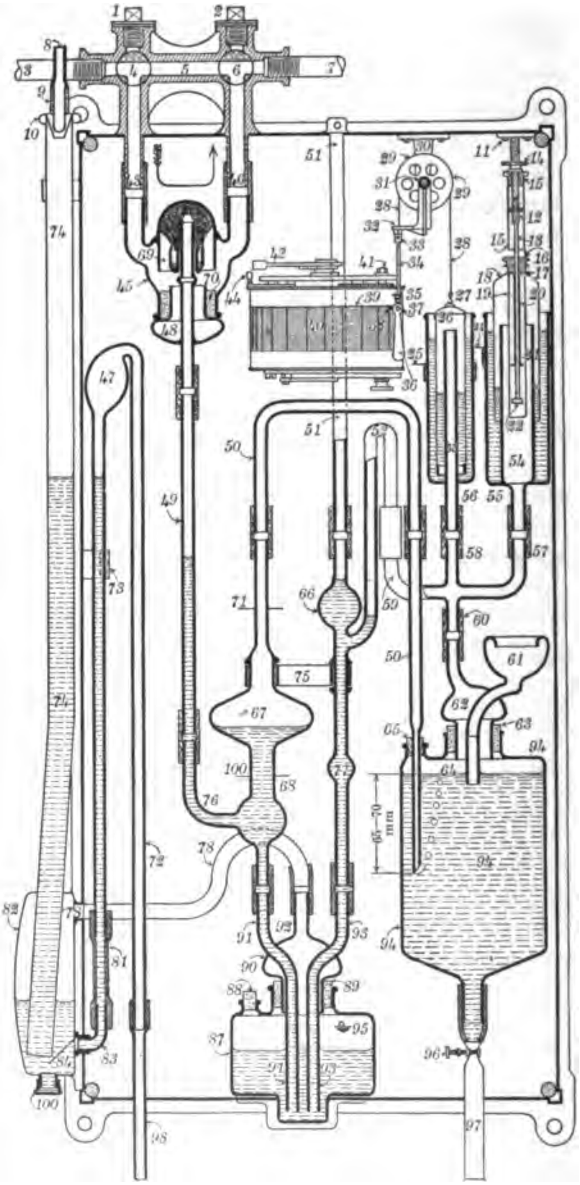

Figure 6.—Parts and connections of Sarco automatic combustion (CO_2) recorder.

Tube *49* is assumed to be in connection with a supply of flue gas; a sample of the gas is drawn from the continuous stream that passes through *43*, *45*, and *46*, as the liquid recedes in *49*, by the partial vacuum created by the falling of the fluid.

As soon as the liquid has dropped below point *76*, which is the inlet of the flue gas into vessel *67*, the gas rushes into this vessel and its connections.

As soon as the flow in the siphon stops, vessel *82* begins to fill again, and the liquids in tubes *91* and *93* rise afresh. The gas in *67* and *68* is now forced into tube *50*, and caused to bubble through a solution of caustic potash (specific gravity 1.27) with which vessel *94* is filled to point *64*, marked on the outside.

In this process any CO_2 that may be contained in the gas is readily absorbed by the potash. As the gas has to pass through the potash, the absorption is rapid and complete.

The remaining part of the sample collects in *62*, and passes up through *60* into tubes *57* and *58*. It can not pass out at *59*, as this outlet is sealed by the liquid in *52*.

The gas now passes under the two floats *18* and *26*. As float *18* is larger and lighter, it will be raised first.

By turning the thumbscrews *14* and *15*, the stroke of this float is adjusted until just 20 per cent of the whole of the sample remains to raise float *26*, when nothing is absorbed in *94*, as would be the case if air is passed through the recorder.

The latter float has attached to it pen *36*, which is caused to travel downward on the chart when *26* rises.

If no CO_2 were contained in the gas, nothing would be absorbed by the potash in *94*, and the whole of the 20 per cent part would reach float *26*. Thus the pen would be caused to travel the whole depth of the chart from the 20 per cent line at the top to the zero line at the bottom. Any CO_2 gas contained in the sample would be absorbed by the potash, a correspondingly less quantity would reach float *26*, and pen *36* would not travel to the bottom of the chart, that is, the zero line.

Thus any CO_2 absorbed will be indicated by the length of the lines on the chart.

On the return stroke of the liquid, the gas is drawn from under floats *18* and *26* through tubes *57* and *58*, and into tubes *59* and *52*. From here it passes out into the atmosphere at *66*, and through tube *51*, as soon as the liquid has fallen below the outlet of tube *52*.

Figures 15 and 16 show instrument 3 as installed for making the tests.

DETAILS REGARDING INSTALLATION.

The position selected for the recorder should not be exposed to great heat or strong drafts. The temperature should be as even as possible and there should be no vibration.

The filter provided with each machine is inserted into the ¾-inch main pipe as close to the boiler as possible. In this position it will keep a maximum part of the pipe system free from soot. The interior of the filter is filled with excelsior or horsehair, which must not be packed tightly, but may be intersected by ½-inch layers of sawdust if the gases are very dirty. The lid dips into a seal of heavy oil or glycerin, which must be kept to the level of the overflow to prevent air from being sucked into the pipe system. The filter is provided with two three-way cocks which control the inlets and outlets so that the line can be shunted through a by-pass pipe, completely cutting off the filter. This is to enable the cleaning out of the pipe to free it from soot by means of steam or air. The lower part of the filter forms a collector for condensed moisture, and should be emptied from time to time by removing the plug at the bottom. An automatic drain is fitted when specially required.

The gas line is brought to the recorder and the final connection is made by a union and a piece of half-inch pipe. A second pipe of three-fourth inch (or, in exceptional cases, 1 inch) internal diameter is tapped into the base of the chimney or into the main flue, well beyond the dampers, thus creating a complete by-pass of gases from the boilers through the recorder and into the chimney. This pipe should also be provided with a fall towards the recorder, and a vertical drain pipe with cock should be fitted, the connection to the recorder being made again by a union and ½-inch piping. The matter of a constant flow through this line is of vital importance, and the exact draft on the two sides of the recorder should always be ascertained before the final connections are made. There should not be less than ¼-inch difference in favor of the chimney side, measured when the pipe system is complete and the filter in circuit and ready for use. If sufficient difference of draft is not obtainable the suction through the recorder must be induced by other suitable means such as a connection to the suction side of a fan, or an insertion of an air, steam, or water injector into the chimney pipe. A small U-tube indicator can be put in parallel with the instrument to show at any time the difference of draft available and also to indicate when the pipe line requires cleaning. The instrument can, by three-way cocks, be by-passed to leave an open line for cleaning.

The operation of the apparatus requires some 3 to 5 gallons of water per hour. The water should be clean and of uniform temperature and pressure. It is preferably supplied by means of a small tank fitted with a float valve and about 2 or 3 feet above the top of the recorder. The level of the water in the tank must be kept uniform. The connection to the little glass aspirator *9* (fig. 6) supplied with the machine is made with a small piece of rubber tubing. With each recorder are sent a number of aspirators with holes of varying sizes, which determine the speed of the instrument. If the water contains impurities the tank should not be set much above the instrument, so that with a low head the size of the aspirator can be large and the aspirator will not tend to clog frequently. The waste pipe should be of 1-inch diameter and must have an open end, preferably funnel-shaped, to receive the water from the recorder. A pipe should also be provided for draining the potash tank.

SETTING UP OF THE INSTRUMENT PROPER.

When all the piping is complete to the point where the recorder is to be erected, the latter is hung on the wall by means of strong hooks or clamps. The recorder must be carefully leveled by the use of the small circular spirit level fixed in the machine, to insure proper working of the pen. One of the glass injector nozzles *9* is selected and attached to the small piece of tubing *8* sent loose with the recorder, the other end of the tube being connected to the ¼-inch water-supply pipe from the tank. The larger float chamber *55* is filled with pure liquid paraffin (specific gravity 0.86) to the top of the brass clip *24*. The paraffin will injure the rubber and must not be spilled on it. In case any has been spilled the tube should be wiped perfectly dry. Then the aluminum float should be inserted carefully, the end of rod *13* being screwed into the socket *11* and locked there by means of nut *12*.

The float should not be dented or damaged, and nuts *16* and *17* should be tight. Collar *15* with its lock nut *14* should be brought to about the position shown in figure 6. The smaller float chamber *56* should also be filled with paraffin to the top of clip *25*, and the brass float *26* inserted. The cotton thread to which the pen gear is attached should be placed over the pulley *29*, and hook *27* fixed to the float. The length of the thread is so adjusted that the float is about one-fourth inch from the bottom of the vessel when the pen rests against stop *32*. The pen should be given a number of twists away from the chart; the torque will then keep it against the paper. This twisting also shortens the length of the thread, thus raising the float, a detail that must be considered when adjusting the length of the thread. Smooth thread must be used as thread that is the least uneven will cause the pen to make a crooked line owing to jerky movement over the brass wheel *29*.

INSTRUCTIONS REGARDING RECORDING PARTS.

In setting up the recording part proper the following instructions should be observed:

Wind the clock, paste one of the charts together and slip it over the clock drums from below, bringing the drums together by moving lever *44* to the right and then letting it slide back gently. Set the chart by sliding it so that the pen points to the time of day. Adjust the length of rod *33* until the point of the pen rests exactly on the 20 per cent line. Fill the container with ink through hole *37*. Assist the passage of this to the pen by removing the latter and passing the wire provided through tube *38*. Moisten also the lips of the pen with ink. If the line produced is too fine, open the lips very carefully by the use of the fine blade, only sufficiently, however, to be just perceptible. Mix one part of the glycerin accompanying the instrument with three parts of water, and fill vessel *87* nearly full, or to point *95* indicated in figure 6. Dissolve in a strong earthenware or glass jar all the potash sent with the recorder, using 43 ounces of water, preferably distilled. Pour in the water and add the potash gradually, a few sticks at a time, stirring the solution. It becomes hot while the potash is dissolving and must be allowed to cool before it is poured through funnel *61* into vessel *94*. The latter should be filled exactly to the little glass projection *64* on the lower end of the funnel tube. If too much has been added, the excess should be drained off by opening clip *96*. The specific gravity of any solution prepared subsequently should be 1.27.

FINAL ADJUSTMENTS.

Instructions as to the final adjustments of the instrument are as follows:

Take out plugs *1* and *2*, setting cocks *4* and *6* to cut off the line and let in air. The temperature of the instrument must be that at which it will be operated; if the temperature changes from day to night, the instrument should be set for the average temperature.

Turn on the water through nozzle *9* into tube *74*. As the water rises in *82* it will compress the air above the water level and through tube *78*. This pressure will act on the liquid in *87*, forcing it up tubes *91* and *93*. The liquid should rise exactly to zero mark *71* on the neck of measuring tube *67*, that mark being reached at the moment when the water in siphon *72* reaches the top and the siphon begins to operate. Should the liquid go higher or lower, adjust the position of siphon *72* after slackening clip *73*. Raising the siphon will cause the liquid in *67* to travel higher, and vice versa.

Adjust until the average is at mark *71*. In making this adjustment care must be taken not to raise the siphon so high as to force the liquid over through elbow *50* into the potash solution, as that would be spoiled. See that the point of the pen stops exactly at zero on the diagram at the moment the liquid reverses. If not, adjust collar *15*; to lower the collar will cause the pen to descend farther, as more of the gas will be apportioned to the brass bell, causing it to rise higher.

About 30 records per hour can be taken. It is not desirable to exceed this speed as the CO_2 will then pass through the KOH too fast, especially when the solution is becoming weak; moreover the liquid piston tends to form more bubbles. Too slow a speed is also undesirable as the liquid forced up from *87* then rises too jerkily, and its levels do not average so well at the time of siphoning. The instrument should be running at the same speed when it is adjusted as when in service.

When adjusting see that, as the liquid rises in *77*, no bubble precedes the level, as this will cause the pen to travel down too far. Such bubbles sometimes occur when the glycerin solution gets heavy after some months of use, and the bubbles do not break well at *77*. See that *66* is held in place by *75*; its action can be checked by seeing that *52* is closed by the rising liquid in *77* at the instant the level in

67 is at the mark *100* on that vessel. Operate for about one hour after all adjustments have been made.

The recorder can now be connected to the gas line. Examine all rubber connections to see that there is no possibility of leakage. Painting all rubber joints and stoppers with asphaltum paint will doubly insure against leakage. In the latest machines the stirrup (*43*, *45*, *46*) has been developed into a filter to prevent particles of soot entering the recorder.

The filter is charged with glass wool, which must be taken out occasionally and washed. Wind the clock daily and keep the pen filled with ink. The levels of the different liquids should be watched carefully. The KOH solution forms water in reacting with CO_2, so that the level of the solution rises a little each day. The higher level affects the reading, and unless the level is at *64* the recorder will not register correctly. The level should be adjusted daily. Add water to the glycerin solution when it gets low in *87*. Keep the paraffin about the bell jars at the same level as when the zero was adjusted.

THE "TELEZOMETER" CO_2 RECORDER. INSTRUMENT 4.

DESCRIPTION OF RECORDER.

The "Telezometer" CO_2 recorder is described with reference to figures 7 and 8. In figure 7, *e* and *f* represent two centrifugal fans driven by the constant-speed electric motor *g*. Fan *f* draws in surrounding air through inlet *h* and forces it out through outlet *k*; fan *e* draws in flue gas through inlet pipe *m* and forces it out through outlet *j*. There exists, therefore, a difference of pressure between *h* and *k* and between *m* and *j*. These differences of pressure vary with the density of the fluid medium. As the CO_2 component of flue gas is much heavier than any other constituent, the density of the flue gas varies with its CO_2 content. Referring to figure 8, the movement of the lever *w* is caused by the resultant of the four static pressures, *m*, *j*, *k*, and *h*, acting on the bell jars arranged as shown. The movement of this lever is recorded by the pen *t* on the clock chart *x* in percentages of CO_2.

In figure 8 the bell jars *1*, *2*, *3*, and *4* are represented as floating in separate vessels, whereas in reality *1* and *2* float in one tank and *3* and *4* in another. The regulation of the inlet and outlet pressures of the air fan *f* is accomplished by means of the pin valve at *h*, figure 7. Through this regulation the instrument can be adjusted to its zero position when both fans are circulating air. Paraffin oil used in the two tanks is shown at *y*.

The remaining parts of the apparatus are shown in figure 7, as follows: *a*, gas filter; *o*, *o′*, drains from the two tanks in which the bell jars float; *p*, *p'*, overflows for these tanks; *r*, manometer inserted in the line *m* for special purposes in testing; *d*, special gage showing the difference of pressure between *h* and *k*, used only for testing purposes; *n*, electric line to motor; *c*, case containing tanks and recording mechanism; *z*, lead connecting tubing.

Because of the difficulty of maintaining the necessary operating conditions in service no instructions regarding the erection and operation of this machine are given herein.

Figure 15 shows instrument 4 as installed for the tests.

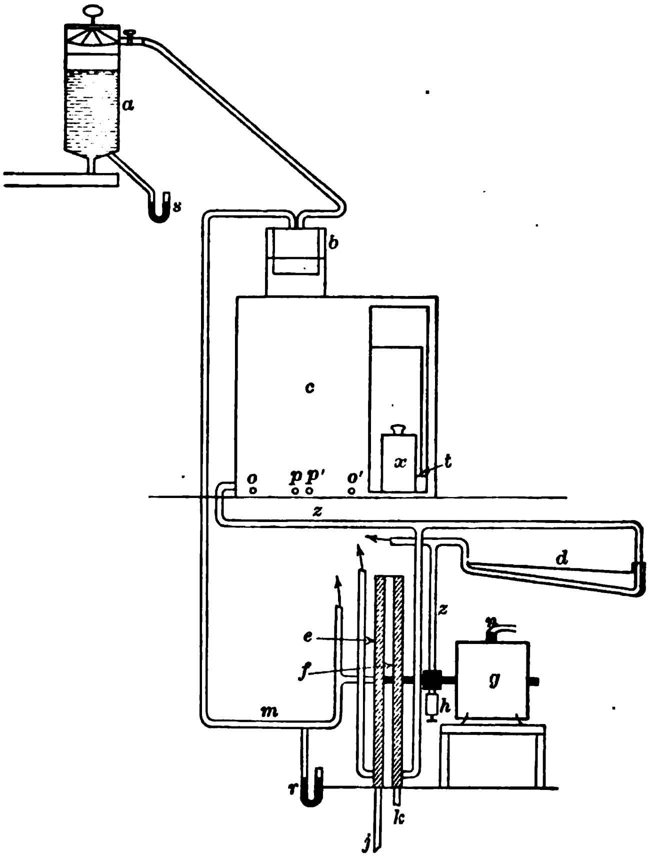

FIGURE 7.—Arrangement of parts and connections of "Telezometer" CO_2 recorder.

UEHLING CO_2 MACHINE. INSTRUMENT 5.

DESCRIPTION.

The Uehling CO_2 machine may be explained by reference to figures 9 and 10, in which the letters and numbers correspond. The instrument is really an open pipe line in which pressures (below atmospheric) are measured at different points. The line has been given its present shape for the sake of compactness. If suction is created by any means at *C''* (fig. 9), gas will tend to flow through the line, entering at filter *D*. At manometer *M* the pressure on the line is measured. The gas passes through valve *J*, and the pressure is measured again at *S*. Here it meets an auxilliary suction, *C*, and tends to divide, the division depending on the relative suctions.

Thence the gas passes through valve *2*, through the small cotton filter *F*, through the steam pot *X* where it is heated to a constant temperature and then meets a high resistance in the form of the orifice *A*. The gas next passes through the caustic *N*, after which the pressure in the line is again measured, this time by *L*, *G*, and *P*., *L*, *G*, and *P*, being the water scale at the front of the instrument, the boiler-room indicator, and the chart recording gage, each measures pressure. The gas now passes through another small cotton filter *F'*, again through the steam pot *X*, where it assumes again its original constant temperature, then meets another high resistance at orifice *B*. Finally it passes through valve *4* out through the suction.

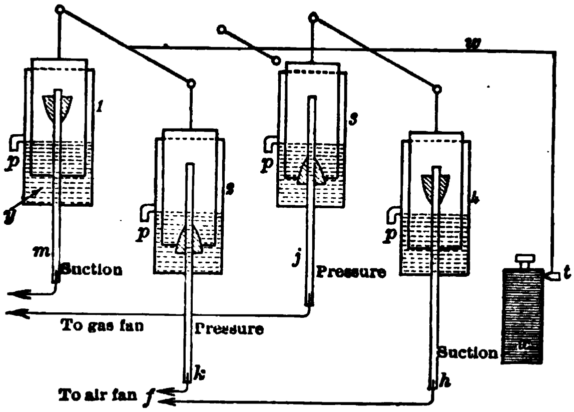

FIGURE 8.—Arrangement of bell jars and connections, "Telezometer" CO_2 recorder.

The method of obtaining the suction *C* and *C''* can be seen from figure 10. If valves *8* (to let in air), *J*, *2*, and *4* are open and valve *5* is slowly opened, a suction is produced, and atmospheric pressure on the water in *H* is lowered. As the suction becomes great enough, air flows in through the center tube *a* and relieves the suction. At the same time air flows in through the line, owing to the suctions *C* and *C''*. The pressure of the suction is registered by tube *v*. Now if manometer *S* is held constant by valve *5*, a certain flow of gas is induced through the recording line; and the gas is kept at a constant temperature by being heated at two points just before it passes

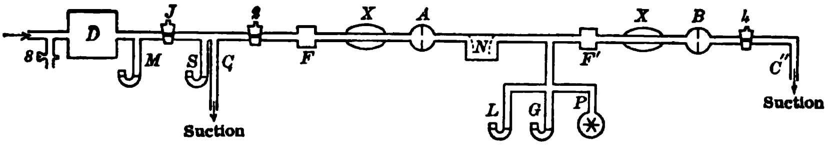

FIGURE 9.—Diagram of essential parts of Uehling CO_2 machine, arranged as a train.

through its highest resistance. *L*, *G*, and *P* will be registering a pressure varying between *C* and *C''*, depending on the resistance on either side. If, for any reason, *L* shows a higher level at one time than another, the indication is that the pressure is nearer to *C''*, that is, that the resistance at *A* or *F* or *N* has increased; if *L* shows a lower level at one time than at another, the resistance *F'* or *B* has increased. If gas containing CO_2 now flows through the line it will give up part of its volume at *N*. This condition could be considered as the resistance between *L* and *C''* being decreased, so that the level of the liquid at *L* will be higher. And so it is necessary only to mark on a scale at *L*, *G*, or *P* the level of the liquid for a gas of a known CO_2 content.

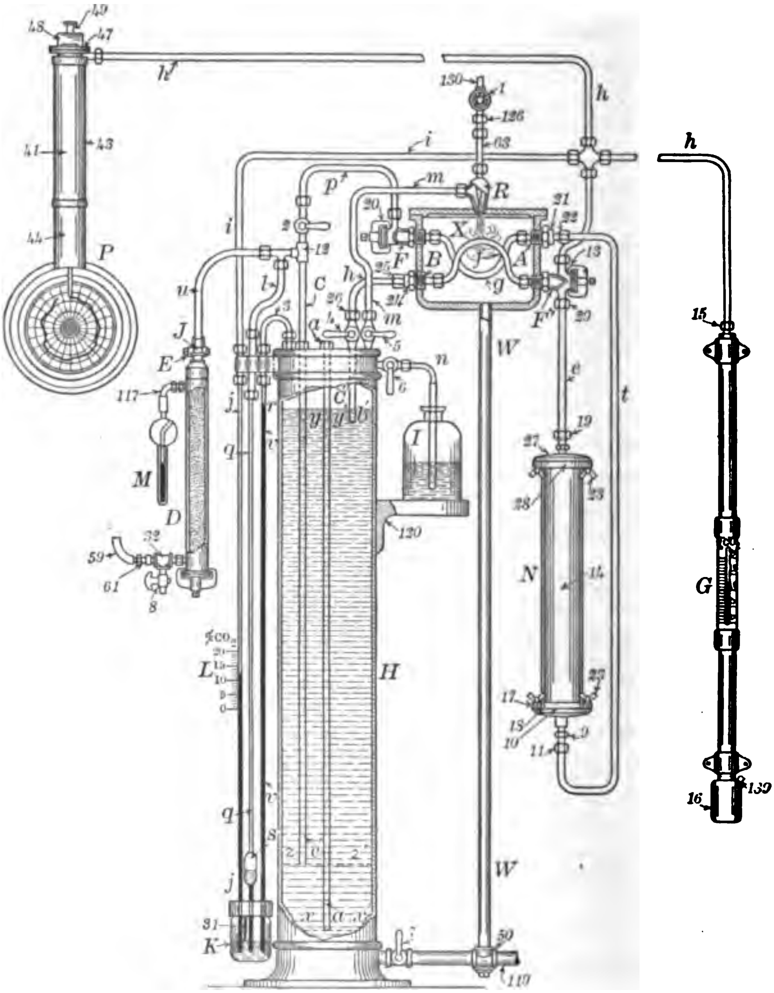

FIGURE 10.—Actual arrangement of parts and connections of Uehling CO_2 machine.

ADJUSTING THE WATER LEVELS.

The various water levels are now ready to be adjusted. See that the recording line is cut off by closing *4* and *2*. Have *J* and *8* open. Turn on steam through the aspirator *R* by means of valve *1;* see that valve *55* (fig. 11) is giving off vapor. Now open valve *5* (fig. 10) slowly until manometer *S* registers at the pointer. A slight bubbling noise will be heard in *H*, and the level of the water in manometer *v* will be somewhere below mark *r*. This level should be raised until it is about one-half inch above mark *r*, by letting more water be sucked through valve *6*, from jar *I*. This raises the head on relief tube *a*, and level *r* comes up. If too much water runs in, valve *7* should be opened and the water let out through the drain. If the water is let out, the steam should be shut off.

Now open cocks *4* and *2*. *L*, *G*, and *P* will register somewhere near zero. Fill *K* until the bottom of the rod *31* is just touching the water. Now check *v* and *S*. Before adjusting for zero, the instrument must be tested for leaks. By closing valve *2* the pressure in the line is much reduced, and the level at *L* climbs up; when it reaches a point about 6 inches above the 20 per cent line, close cock *4*. Let the levels of *L*, *G*, and *P* come to a standstill. They should remain there unless there is a leak in the instrument. If the levels will stand at the 15 per cent line for several minutes, the adjustment is satisfactory for practical working.

TESTING FOR LEAKS.

If a leak is indicated, it will probably be in the connections made when setting up. These should be gone over carefully. Each unit can be tested for leaks independently if necessary. A leak is most likely to occur in the joints of the absorption chamber *N* which holds the caustic carton. Before looking elsewhere for a leak, make sure that absorber *N* is properly placed, and that the rubber rings are in their proper position. All connections are of drawn-copper tubing with a soft-copper flange and brass nut on each end. Connection is made with a hard-brass knife-edge surface which cuts into the soft copper, thereby making a joint absolutely tight. If, for any reason a connection is taken apart, care must be taken that the knife edge fits into the same groove that was made in the copper flange when connection was first made.

To blank off the boiler-room gage, disconnect near filter *F′*. Close the opening made by the removal of the tubing by a copper blanking disk and nut. Try the machine again for leaks. To test the indicator alone, disconnect the tubing at *15* and place the tubing in the mouth. Suck up the column of oil until it reaches the 20 per cent line, and close the opening with the tongue. If the column stands steadily the leak is in the tubing or connections; if not, the leak is in the indicator itself in the joint between top piece *15* and the glass tube. This top piece with glass tube can be removed by loosening the set screw. The joint between the glass tube and the top piece is made by means of a rubber gasket on the glass tube with a washer and nut. In the same manner the recording gage can be blanked off.

To test the recorder alone, disconnect the tubing at the top of the recorder. Screw off the recorder name plate. Through the opening in front lift up the counterweight until the pen point reaches the 20 per cent line. Close the opening at the top of the gage. The pen should not sink. The most likely leak is about cap *47*. If there is reason to believe that the leak is in the machine proper, go over the line carefully, tightening up connections, caps, etc. There is small chance for a leaky valve, but should a valve leak, the leak can be stopped with a little vaseline. To make sure that the leak is not in the absorber *N*, disconnect copper tube *t*, blank off the bottom connection of the absorber *N* with nut and disk and test for the leak in the ordinary way. In this manner and by ways that easily suggest themselves a leak can be traced and fixed. Asphaltum paint can be used to good advantage in many places. Not much trouble should be experienced from leaks.

ADJUSTING FOR ZERO.

To adjust for zero, the following method should be used. Let the machine run on air for about 15 minutes. See that the levels in *S*, *v*, and *K* are correct. If it is necessary, lift the pen of the recording gage to raise the float from its seat, to which the float sometimes sticks. The chart, the boiler-room gage, and the instrument gage should read somewhere near zero. Close valve *4* for an instant, long enough to allow the liquid in water gage *L* to drop one-half inch; then open again and let the liquids in all gages come to rest. Note their positions, and repeat a few times. Let them stand 10 minutes, then move the scale on the instrument to make its zero point at the water evel in *L*, slide the small pen of gage *P* on its support so that it will register correctly, and adjust the boiler-room gage by twisting *16*. The oil moves rather slowly and it may take some time to adjust *16*.

The instrument can now be trhown on the gas by closing *8*, and the CO_2 content can be registered. Manometer tube *M* shows the suction on the gas line. It should not go over 1½ inches. Too great a suction is probably due to filter *125* (fig. 12) being clogged. If the gas line becomes clogged the tube will bubble, thus relieving the line. In continuous running the condition of the carton *N* (fig. 10) can be told by the position of the zone of highest temperature upon it. CO_2 combines with KOH with an evolution of heat, and this heat zone in a fresh carton will be at the bottom where the gas enters. As the caustic is used up the zone of reaction or the heat zone moves up. The heat zone can easily be followed with the hand, unless the room is cool and the percentage of CO_2 is low, and when the zone gets to the top the carton is used up. In stopping the machine close *5* ahead of *1*, as otherwise the steam may condense and be sucked into *H*, thereby raising the water level in *H*.

MISCELLANEOUS DIRECTIONS.

Wind the clock daily. Filter *125* (fig. 12) should be replaced as necessary, depending on the condition of the flue gas sampled. If there is any discrepancy between the indication of the recording gage and that of the water column at *L*, a discrepancy most apt to occur when the CO_2 content is between 10 and 15 per cent, it will be necessary to set the gage at these points, correcting for the difference, rather than at zero. The difference will not involve an indication of more than 0.5 per cent CO_2.

After some time of continuous running, differences in indications may appear. If the water level in bulb *S* (fig. 10) is high, make sure that the water level in *K* is right. Adjust valve *5*, making sure that the suction in *v* is not broken by closing *5* too much. If the level in bulb *S* is still high, take out core of cock *J* and make sure aperture *E* is clean. If cleaning aperture *E* does not bring the 6-inch suction in *S* down to the index, then the cotton in filter *D* may be packed too tightly or may have gotten wet from the water in the U-bulb *M*. To clean filter *D*, open it at the bottom. When clean cotton is replaced, be sure that it is put in loosely. In replacing the cap be sure that a tight joint is made by means of a rubber gasket. If the suction bulb is low after adjusting valve *5*, make sure that the core of the cock *J* is not loose and that the connecting points of copper tubes *u* and *l* are tight.

Each time a new carton is inserted test for leaks and adjust for zero as described. The cartons have different resistances and each new carton may change the zero adjustment slightly. Also in course of time the zero may get so high as not to be reached by the sliding scale. The variation is due to aperture *A* or filter *F* getting clogged. Change the cotton in filter *F* and make a good joint when replacing the cap. If the zero is still high, take out aperture *A*. Break the connection between tube *t* and *22* and screw out the nut, when the aperture holder can be pulled out. Hold the aperture piece under a jet of dry clean steam such as would issue from the full pressure line through a pet cock. A pet cock for this purpose should be put up permanently in some convenient place. The aperture piece can be held by means of a clean pair of pliers. Allow steam to play on the platinum center of the aperture piece for 15 to 20 seconds on each side. Do not touch the tiny hole with anything, as around its edges is a selvage that may be bent over, thus changing the size of the orifice. The piece should be held no farther than an inch or two from the nozzle of the pet cock.

Replace the aperture piece in the holder in its original position. See that it fits in the holder just tight enough so as not to fall out when the holder is turned over. After several replacements the copper may bulge, owing to the pressure, and may become too tight in the holder. It then can be filed down. When replacing the holder, make sure that the steel key on its surface will be in line with the groove for it in the casting. Push the holder into place and tighten the nut. The joint is made tight by the knife edges of the holder and the casting, which embed themselves into the copper of the aperture piece; hence the nut should carefully be set tight.

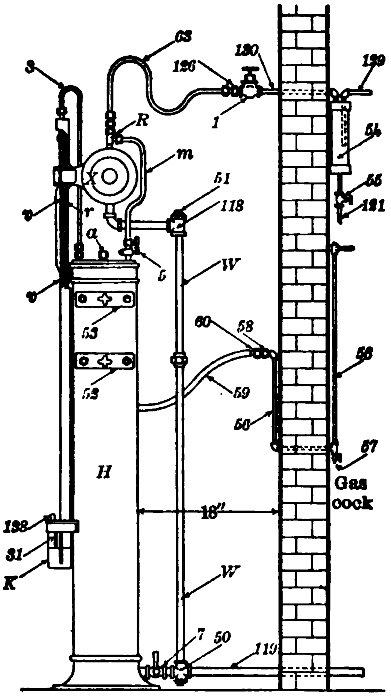

FIGURE 11.—Diagram showing how Uehling CO_2 machine should be set up.

Figure 16 shows instrument 5 installed for the tests.

SETTING UP THE INSTRUMENT.

The instrument must stand firmly and should be at least 18 inches from the wall and so placed that the scale can be easily observed (fig. 11). The condensing filter should be fastened by means of a bracket to the side of the boiler or elsewhere in a position where the bell *89* (fig. 12) can be easily reached. A ½-inch water pipe, *128*, must be connected as shown in figure 12 and should be supplied with a valve, *72*. Tee *78* should be connected with a drain by means of a ¾-inch iron pipe, *134*. The drain should be led to a place where the outflowing water can be seen, so as to make sure that water is flowing through the condenser.

HOW CONDENSING FILTER FUNCTIONS.

Figure 12 clearly shows the function of the condensing filter. The water enters through the flexible-rubber connection *76*, passes through *81*, at the top of which it overflows through pipe *83*. The water then fills the seal *84*, whence it overflows into the bottom seal *86*, leaving finally through pipe *134*. The gas passes through *88* to *82* to *132* to *133*, thence through the filter *125*, from which it leaves through the flexible connection *75* and arrives at the instrument by means of the ¼-inch gas pipe *56*. The flexible gas connection *75* makes it possible to lift the bell *89* out of the water seal *84*. The cylindrical filter *125* can then easily be removed and replaced. Each condensing filter is supplied with two cylindrical filters *125*, one of which is kept in readiness and filled with fresh waste loosely packed to take the place of the second as soon as it becomes fouled.

PRELIMINARY PIPING.

The ¼-inch gas pipe *56* for the gas from the condensing filter (fig. 12) should be brought to the instrument as shown in figure 11. The bend in the line is to catch any vapor in the gas that might condense during the operation of the instrument. This condensation can be let out through the gas cock *57*. If there is more than one CO_2 unit a separate gas line, *56*, must be put up for each unit. The flexible gas connection *59* is furnished with each unit and is supplied with a ¼-inch nipple, *58*, to fit the ¼-inch gas line from the boiler. The other end of the connection *59* is attached to gas inlet *32* (fig. 10).

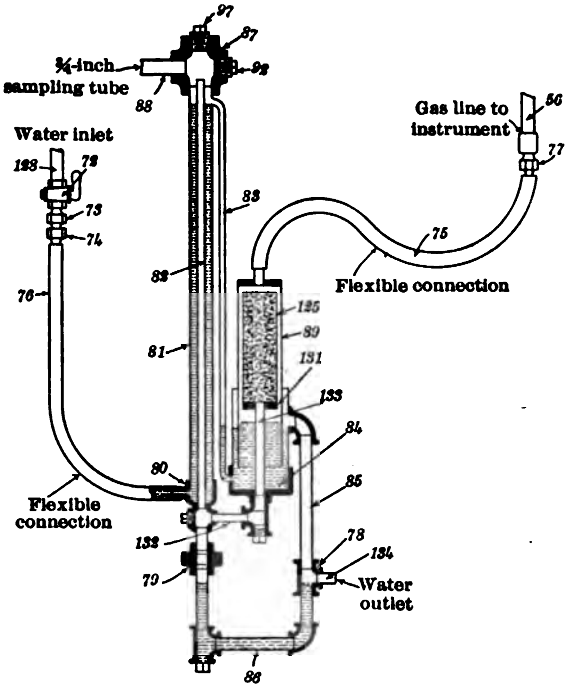

FIGURE 12.—Condensing filter and connections, Uehling CO_2 machine.

Dry steam must be brought to the place where the instrument is to be placed. To insure dry steam a separator, *54* (fig. 11), can be made, or a simple drop bleeder pipe can be used. The separator is made of a 3-inch iron pipe about 3 feet long, with a cap on each end; a ¼-inch steam supply pipe, *129* (fig. 11), should extend about halfway down the length of the separator; the outlet should be a ¼-inch pipe, *130*, fitted with a ¼-inch valve, *1*. It should be drained with a ¼-inch iron pipe at the bottom, and supplied with a valve, *55*. This drain pipe should be led to a point where the outlet is visible, so that a slight vapor can be made to flow continually from the pipe by adjusting the valve *55;* the continuous escape of a small volume of vapor from pipe *121* will insure dry steam. If the simple bleeder pipe is used, the line *129* is arranged to drop vertically a few feet just before reaching valve *1*, where a tee is inserted, into the outlet of which is fitted pipe *130*. The run is carried down another foot and a bleeder valve is placed. This, like valve *55*, should be left partly open.

Before connecting the instrument, blow out the steam line to clear it of foreign material.

Provision also must be made to take care of the drain pipe *119*. If the recorder is close to the filter, this drain pipe should not be connected to the filter drain, as the steam might back up into the filter, raising its water level, flooding the filter waste, and cutting off the gas supply to the instrument.

SETTING UP CO_2 RECORDING GAGE.

Each recording gage as shipped is ready to be screwed to the wall. The recorder must be so fastened to the wall or gage board that mercury vessel *43* (fig. 10) will be absolutely plumb. After the recorder is in place, remove cap *47* by loosening clamp *48*. Remove from the inside of the mercury vessel the block of wood which is put there to hold bell *41* in place for shipment. After the block of wood has been removed, pour into the opening at the top all the mercury furnished for the gage. After the mercury has been poured in, add the contents of the small bottle, a special oil with which to cover the mercury to prevent oxidation. After the mercury and oil have been poured in, replace cap *47*. See that a rubber band is around its neck before replacing the cap, so that a tight joint can be made by means of clamp *48*. Do not force the screw *49*.

After the cap *47* has been properly replaced, the gage will be ready for connection with the main instrument. Connection is made by means of a $\frac{3}{16}$-inch drawn-copper tubing with flange and nut at each end. Have as few bends as possible in this tube, which will be found in the box with the recorder. One end is joined to the connection at the top of the recording gage and the other end to one of the connections on the filter *F′* at the steam pot (fig. 10). Filter *F′* is the small aperture filter with which the top of absorption chamber *N* is connected. All connection points will be found blanked off with nuts and disks, which must be removed and saved for possible future use.

SETTING UP AUXILIARY CO_2 INDICATOR.

The indicator *G* is usually screwed to the boiler front or any other place convenient for the fireman's observation to serve as a guide in firing.

After the indicator has been properly fastened, screw out plug *139* and pour into reservoir *16* the special indicator oil furnished with the instrument. This oil will be found in a can marked "Special oil for CO_2 indicator." The entire contents should be poured into the reservoir *16*, and the plug *139* should then be replaced. The auxiliary indicator is connected with the instrument by means of a $\frac{3}{16}$-inch drawn-copper tube with flange and nut at each end. This tubing will be found in the box with the main instrument. One end is connected to the top of the indicator and the other end to one of the connections on filter *F′* at the steam pot.

FILLING REGULATOR.

Before connecting the instrument with the drain pipe *119* (fig. 11) unscrew plug *51* at the top of the exhaust pipe *W* and insert it into the open end of cross *50*. Open cock *7*. Insert a funnel into tee *118* and pour in exactly 11 gallons of clean water. Then close cock *7*, take out the plug that was inserted into cross *50*, and replace it tightly into fitting *118*. See that cocks *6*, *5*, *4*, and *2* on the instrument (fig.10) are closed and that cock *J* at the top of the filter *D* is open. The core of this cock must be in such a position that the small cross mark is horizontal and at the bottom.

INSERTING CAUSTIC CARTON.

To insert the caustic carton *14* (fig. 10), loosen wing nuts *23* at the top and bottom of *N*, remove *N* from between *27* and *18* and punch 15 to 20 large holes into each end of the carton with a lead pencil. Put the round rubber ring *10* around the bottom end of the carton. Push the carton into *N* and replace *N*, making sure that the carton sets down against cap *18*, as shown in figure 10. A round rubber ring between *27* and *28* will be found in place, where it must remain. The rubber ring at the top is not placed around the carton and only prevents leakage between *27* and *28*. Rubber ring *10* makes a tight joint between *17* and *18*, and, as the wing nuts are tightened, makes a tight joint about the carton, preventing the passage of gas around it.

Fill vessel *K* with clean water up to index rod *31*. Connect the aspirator *R* with valve *1* by means of copper tube *63* (fig. 11). This tube is 2 feet 6 inches long and will be found tied to the exhaust pipe. It can be bent to fit. It has at one end a nipple, *126*, that will fit the $\frac{1}{4}$-inch valve *1*.

THE CO_2 THERMOSCOPE. INSTRUMENT 6.

DESCRIPTION.

The CO_2 thermoscope consists of the following main parts: (1) A cylinder fitted with a plunger for drawing from the flue the gas mixture to be analyzed; (2) a small cartridge-shaped receptacle containing granular caustic alkali, in which the heat reaction occurs; and (3) a special thermometer with its bulb constructed to surround or jacket the cartridge so that the heat of reaction can be imparted to the mercury, the amount of its expansion (read as the percentage of CO_2) being observed on a movable scale.

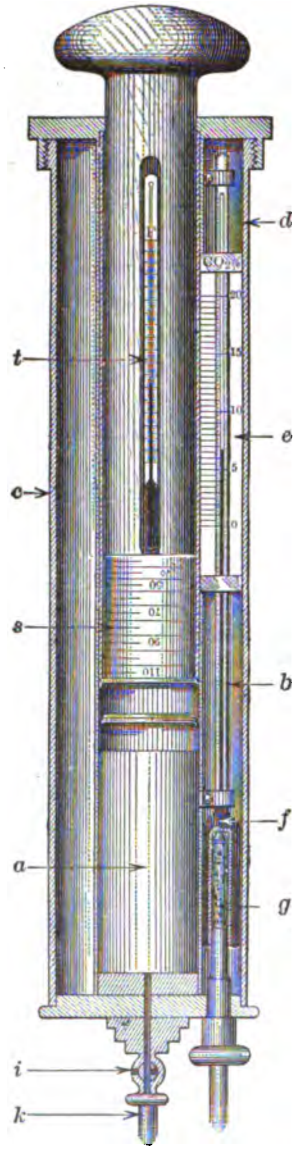

FIGURE 13.—The CO_2 thermoscope.

Figure 13 clearly shows the parts and their relations. At *a* is shown a cylinder fitted with a piston and cup leathers and provided with a three-way cock *i* at its end.

The thermometer *b* is mounted on the cylinder *a*, and the whole is inclosed by the cylindrical jacket *c*, which is slotted at *d* to show the thermometer stem. A movable scale *e*, calibrated to show percentages of CO_2 by volume, is arranged to slide in the slot.

The thermometer bulb *f* is blown so as to form a cylindrical jacket, in which is inserted the cartridge *g*, containing caustic alkali in the form of a dry granular powder. When the instrument is to be used, the cartridge is pricked at each end. In order that the gas under examination may flow through, a needle mounted in a cavity in the end of the piston rod is used to prick the carton. At *k* is a rubber-tube connector for delivering the gas from the cylinder *a* to the interior of the cartridge.

In order to correct the volume of the gas drawn into the cylinder for varying room temperatures, the length of the piston stroke when taking the sample is regulated by a temperature scale *s* on the piston rod, the room temperature being read for convenience on the thermometer *t*, which is placed in a cavity of the piston rod, or by any thermometer in the room.

MAKING AN ANALYSIS.

Directions for making an analysis are as follows: Place the rubber connection *k* over the nipple at valve *i*. Its end for the brass cartridge will fit nicely into any ordinary rubber hose that will carry the sample from the sampling tube.

In handling the instrument do not allow the hands to grasp it at the bottom end where the thermometer bulb is located, as the heat of the hand will move the mercury, and time will be lost in waiting for it to come back to room temperature.

Prick a cartridge at both ends, using the needle in the end of the piston rod, and lay aside for the moment. Draw the gas sample. By operating the three-way cock at each stroke the instrument works as a pump. Thus after a few strokes the pipe leading to the sampler is cleared and an undiluted gas sample is obtained. Break the connection between *k* and the sampling pipe and place the cartridge snugly on the end of *k*. Insert the cartridge into the thermometer bulb *f*. It should fit and stay up tight to the rim on the rubber.

A wait of 1½ minutes to 3 minutes is necessary after the cartridge has been placed in the thermometer, as the warmth of the hand in making it ready will cause a rise of the thermometer equivalent to about 1½ per cent CO_2. If this care is not taken, the analysis will show too high a CO_2 content. Compress the pump to the proper temperature mark on the stem, that mark being read on the room-temperature thermometer. Pull the connector off the valve *i* for the instant and open *i* to the atmosphere to create atmospheric pressure in the pump. There should be a slight puff as the gas in the pump is under a slight compression above atmospheric. Replace *k* and adjust *i* so that the gas will flow from the pump through the cartridge.

Set the sliding scale *e* with the zero at the end of the mercury column. Be sure that all rapid movement of the column has ceased, or that it is at a point representing room temperature for the column, and hence will make no changes due to that source. Force the gas through the cartridge. The stroke should be smooth and easy, requiring about five seconds. A few seconds more or less than five will result in a CO_2 indication 0.5 to 1 per cent low. Six seconds is much preferred to four seconds. If the stroke seems rather hard, a passage is probably stopped up partly, and good results can not be had. The heat due to the chemical action will now heat up bulb *f*, and the maximum point to which the column rises will register the CO_2 content.

The greatest source of error is in trying to make too many analyses per hour. Six records per hour is a maximum number unless artificial cooling of the indicating thermometer bulb is used. If, after one analysis has been taken, another is attempted before the mercury, although seemingly stationary, has returned to its original position of zero on the scale, a low result of several per cent will be caused. If the instructions are followed carefully, an error of 0.3 CO_2 is the maximum that may appear

DR. A. SCHMID'S POCKET CO_2 INDICATOR. INSTRUMENT 7.

The Dr. A. Schmid's pocket CO_2 indicator is shown in figure 14. Cock *a* is removed and a solution of KOH (250 grams of potassium hydrate dissolved in 1 liter of water) is poured into the lower bulb by means of the small funnel furnished. One filling is enough for about 200 determinations of CO_2. When the instrument is not in use, a rubber stopper is inserted in place of glass cock *a*.

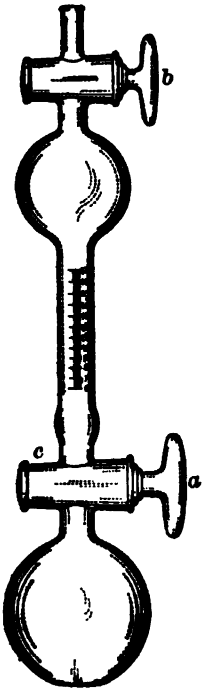

FIG. 14.—Dr. A. Schmid's pocket CO_2 indicator.

MAKING A DETERMINATION.

To make a determination, the glass cocks *a* and *b* are put into place, *a* being the cock with one blue tip. The rubber pump furnished is placed on the glass nipple above cock *b*. The other end of the pump is placed on the gas line from which sample is to be taken. Cock *a* is so placed as to throw the small hole *c* open. Gas is then pumped in. The lower cock is closed, the rubber pulled from the top, and the upper cock closed. This arrangement insures atmospheric pressure in the bulb at the start.

The lower cock *a* is now opened with the blue tip downward. The instrument is held inclined downward and shaken until the upper bulb is about half full. It is then stood upon its base and the gas in the lower bulb comes up, a bubble at a time. When the KOH has found its level, the lower cock is closed. The instrument is now held upside down and lowered vertically into water. The submerged cock is opened and the ingoing water is leveled with that outside. In leveling the water in the submerged bulb with that outside an error as high as 0.3 per cent can be made.

To get accurate results, use a glass beaker large enough for convenient manipulation of the submerged cock, and take the leveling sight from below the water level. Place a light back of the beaker if necessary. The cock *b* is closed and the instrument stood on its base. The small stem above cock *b* should be completely filled with water, as the water is to replace the air forced into the indicating tube from the stem when the instrument was lowered into the water. The upper cock is now opened just long enough to allow the water to run down into the tube. After some 30 seconds, the exact number depending upon how dirty and sticky the side walls are, the percentage of CO_2 is read. The instrument is turned upside down, and cock *b* opened, and the instrument is ready for another sample.

MISCELLANEOUS INSTRUCTIONS.

As the walls of the vessel have a coating of KOH on their sides, the incoming water is made highly alkaline; after the water has been poured out the walls are still alkaline. The next sample is liable to have a part of its CO_2 content removed by the caustic solution on the walls of the instrument before it is closed from the atmosphere. Therefore the instrument should be purged by pumping gas through it. The purging will require some 20 or more strokes of the pump, the number depending on the gas and the solution. If this precaution is not taken, the result will be a low CO_2 indication. As the second sample is pumped in, it puffs out little drops of water from the small hole in the lower cock. The water thus ejected is highly alkaline and should be caught with some waste or it will run down on the lower bulb and get on the operator's hands when the instrument is shaken.

Much care must be taken to insure that the glass cocks move easily and without any air leakage. The lower cock is apt to bind because of the action of the caustic. Keep plenty of vaseline or its equivalent on the cocks. As the caustic during manipulation is apt to get a little low, water can be let down to fill the lower bulb.

In order to determine the maximum error due to temperature changes incident to the manipulation of the indicator, proceed as follows: Make one determination of the CO_2 content of a sample of gas in the ordinary manner, being careful to keep the hands off of the upper or gas bulb of the instrument as much as possible. After taking the reading hold the hands on the gas bulb for some time; then relevel quickly in the water and take a second observation of the CO_2 indication. The difference between the two observations represents the maximum error due to temperature changes.

With careful manipulation an analysis will take about three minutes. Determinations made in this way will be accurate within ±0.2 per cent CO_2.

GENERAL CONCLUSIONS FROM TESTS.

The following brief summary of conclusions from tests of the CO_2 recorders herein described indicates the scope and character of the tests. The conclusions are amplified in subsequent pages.

1. Evidence of a change in the composition of a gas being tested is shown by each of the recording instruments soon after the change takes place, the maximum time for such evidence to show being 8 minutes. The correct registration of the percentage of CO_2 (permissible error 0.5 per cent) requires a longer time, which varies considerably with the type. Such changes indicate the lag of the instrument, defined as the time interval elapsing after gas enters the instrument and until the CO_2 content is correctly registered on the chart.

The item of lag may or may not be important, depending on the purpose for which the instrument is to be used. The lag of the system will be the lag due to the instrument plus that due to the piping to the boiler, the latter depending on the length and diameter of pipe used.

2. When properly set up, and so long as the instrument remains in adjustment, the error of the record, when the composition of the gas is not changing, varies between 0.1 and 0.5 per cent CO_2, according to the type of instrument.

The introduction into the system of gas-storage capacity, such as a large filter, will result in a reduction of the fluctuations of the record curve, although the average will be the same. It should be pointed out that the cross-sectional area of the gas stream in the filter is also a factor affecting the form of the record curve, for if the area is large diffusion will take place, and a longer time will be required to purge the filter.

3. Changes in the temperature of the surrounding air, in the boiler draft, and in the speed of the instrument caused an appreciable error in the CO_2 record for some types of recorders.

4. The life of a single charge of the alkaline reagent used in all recording instruments (except No. 4) for removing the CO_2 content from the flue gas varied from 500 to 5,100 per cent hours, according to the type of instrument. Per cent hour is defined as the product of the CO_2 content and the number of hours the gas was being analyzed. For example, 1,000 per cent hours would mean an indication of 10 per cent CO_2 for 100 hours or a 5 per cent gas for 200 hours.

5. The ordinary daily attention necessary, such as winding the clock, changing the chart, and inking the pen, will require 5 to 15 minutes of the fireman's time once a day. Adjustments, changing of reagents, and any special care should be left to the engineer or some one else who thoroughly understands the instrument. The amount of such attention that will be necessary will vary from time to time and with the type of instrument. The time required to change a reagent differed considerably for the several recording instruments, ranging from 5 to 45 minutes.

6. The expense of maintenance (not taking into account the time required for adjustments or other special attention) was, for the several months during which the instruments were being tested, practically confined to the cost of the reagent.

7. The observations of CO_2 content made with the proper manipulation of the indicating (not recording) instruments were correct within 0.3 per cent CO_2. The care and skill required for such operation depended on the type of indicator.

8. With each instrument it is necessary for some one in charge to become entirely familiar with the principle and the manipulation of the instrument. The things that may happen to the instrument to interfere with its proper working are usually easily remedied, but are not always evident to casual inspection, and therefore a considerable

degree of patience and understanding is required to insure continued operation. The character of the instrument, moreover, is such that it should be placed in the charge of some one who is qualified to handle instruments or mechanisms of a delicate nature. This service is not beyond what can reasonably be expected from an engineer employed in plants likely to profit by an investment in such an instrument. It is believed that much of the trouble with these instruments arises from the fact that the persons who are responsible for their proper operation are not thoroughly and properly instructed. This oversight is probably due in part to the fact that the seller does not feel justified in taking the time to follow up the sale of an instrument by thoroughly instructing the employee of the buyer who is to operate the instrument. Such action is believed to be necessary to the successful installation of these devices.

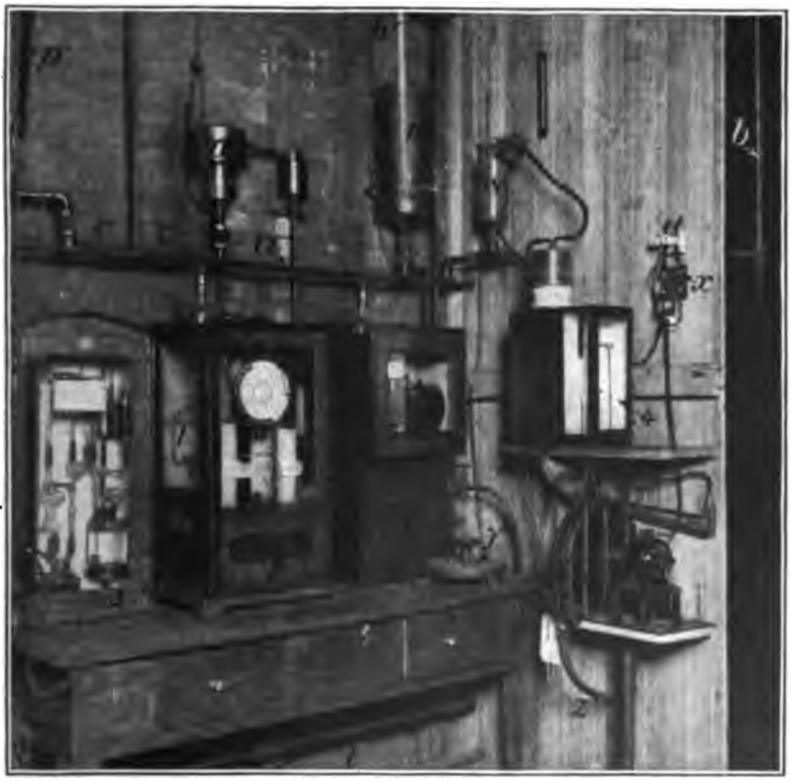

FIGURE 15.—CO_2 recorders 3, 2, 1, and 4 as set up for tests.

ARRANGEMENT OF APPARATUS IN THE TESTS.

The various instruments were, in all essential details, set up according to the makers' instructions. In order to obtain the desired data the apparatus was arranged as shown in figures 15, 16, and 17.

In figures 15 and 16, *a* represents the main gas line of ¾-inch piping connecting the instruments to the sampling tubes of several power boilers any one of which could be thrown on the line. The gas line was about 45 feet in length. The line *b* (fig. 15) was an auxiliary line from the gas tank or gasometer *g* (fig. 17), which could be thrown on and off the main line by the manipulation of the proper valves. Gasometer tank *g* (fig. 17) was a water-sealed bell; the pressure within the bell, shown by gage *k* (fig. 17), could be controlled by the balancing weights *h*. This tank could therefore supply

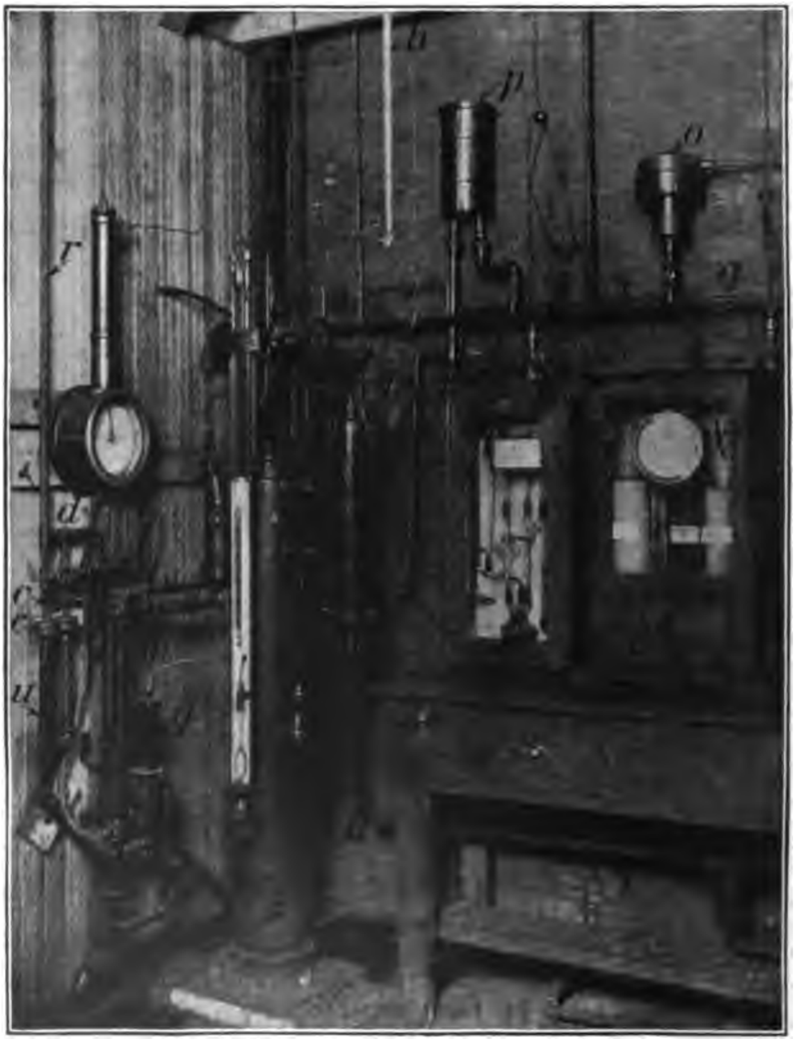

FIGURE 16.—CO_2 recorders 5, 3, and 2 as set up for tests.

a gas of uniform CO_2 content at any pressure for standardizing purposes.

At the instrument end of line *a* was a drop bleeder pipe to catch the moisture, which was removed by taking off a cap at the end of the drop. Here also compressed air could be connected to clear out the whole line. Aspirator *c* (fig. 16) at the end of the line kept a constant flow of gas through the piping, in addition to that which the instruments were causing. The draft on the line was shown by gage *d* (fig. 16).

Filters *w*, *n*, *o*, and *p* (fig. 15) were piped from the top of the gas line, and *mq* (fig. 16), the condenser filter for machine 5, was connected at the end as shown. From these different points the instruments, with the exception of instrument 3, were connected according to the maker's directions. The makers connect instrument 3 in such a manner as to cause a continuous flow of gas along pipe *j* (fig. 6). In order to simplify the piping layout there was substituted for this a flow along pipe *j* caused by aspirator *e*, the draft of which was shown by gage *f*.

Water was supplied from a tank placed on top of the recorder booth and equipped with a float valve so as to keep a constant head of water at the instruments. The water for aspirators *c* and *e* and for instrument 5 was supplied by the pipe *r*. Line *t* took the drainage from instruments 1, 2, and 3, as well as the water drip from the steam line *s*. Line *u* carried the drainage of the aspirators *c* and *e* and of the condenser filter *q*, and served as the drain for the steam aspirator of machine 5. The outlet for machine 4 was at *z* (fig. 15). The electric current was brought in at switch *x* (fig. 15) for machine 4 and passed through the controlling resistance *y* before reaching the motor.

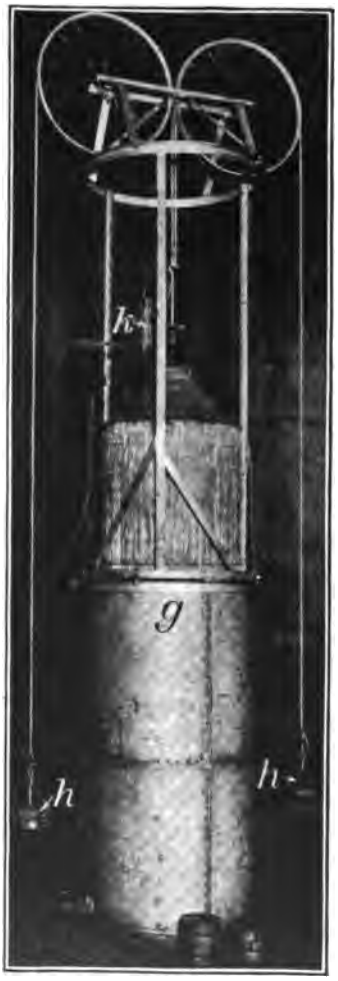

FIGURE 17.—Gasometer tank.

OUTLINE OF TESTS.

The tests of the instruments may be divided into two classes, as follows:

First, special or laboratory tests, which include the determination of the lag and of the effect of changes in boiler draft and room temperature, also any tests suggested by the mechanism of the instrument itself and peculiar to it.

Second, endurance tests, in which the instruments were run day after day on the gas from a power boiler, as would occur in practice.

In order to ascertain the lag of each instrument, it was run at a definite speed under regular working conditions, with a constant draft and temperature, and drawing a gas of unvarying CO_2 content through its filter and gas line. The gas was drawn from the gasometer, and its exact CO_2 content was determined by a number of analyses in the chemical laboratories. After the CO_2 content had been registered correctly as shown by several determinations, a gas of different CO_2 content was admitted to the line and the time that was required for the instrument to correctly register the second gas was noted. In some instances, the gas was also admitted directly to the instrument proper thus eliminating the lag due to the filter and gas line.

To determine the effect of a change in boiler draft the devices were supplied with gas of uniform CO_2 content, and the draft pressure was varied by means of the balance weights on the gasometer, the temperature and speed being kept uniform.

To determine the effect of a change in the surrounding temperature, the CO_2 content, draft, and speed were kept uniform, and the sursounding temperature was suddenly lowered and held at the lower temperature.

The endurance tests consisted in operating the machines under service conditions and noting all the care and attention necessary to keep them recording correctly. These tests covered a period of several months. Every eighth day the devices were standardized by allowing them to run on gas of known CO_2 content taken from the gasometer to ascertain whether they were still recording correctly. By this means the required frequency of renewal of the reagents was also determined.

The tests of the indicating instruments consisted of an extended series of analyses of gases of known CO_2 content. The tests indicated the proper manipulation, the skill and care required for such manipulation, and the errors likely to occur in the handling of the instruments.

TABULATED RESULTS OF SPECIAL TESTS.

The tabulated results of the special tests follow. The graphic records mentioned in the tabulation are shown in figures 18 to 22. Graphic records obtained from the recorders under normal operating conditions are shown in Plate I and figures 23 to 25.

Tabulated results of special tests of CO_2 recorders.

TESTS FOR LAG.[a]

Instrument No.	Change of gas.	Speed of recorder.	Time taken to make completed record.	Time taken to make record within 0.5 per cent.	For graphic record, see—
	Percentage of CO_2.	*Records per hour.*	*Minutes.*	*Minutes.*	
1	6.0 to 0.0	17	41	30	No. 1, fig. 18.
	0.0 to 6.5	17	39	35	No. 2, fig. 18.
	6.5 to 4.5	19	35	20	No. 3, fig. 18.
2	9.0 to .0	16	33	22½	No. 1, fig. 19.
	0.0 to 6.5	16	34	23	No. 2, fig. 19.
	7.0 to 2.5	16	34	23	No. 3, fig. 19.
	[b] 8.5 to .0	16	13	9½	No. 4, fig. 19.
3	[b] 6.5 to .0	48	9	5	No. 2, fig. 20.
	[b] 0.0 to 6.5	48	16	14	No. 1, fig. 20.
					No. 3, fig. 20[c].
		Revolutions per minute.[d]			
4	0.0 to 10.7	1,660	8	6	Nos. 14–1, fig. 21.
	0.0 to 7.5	1,660	5	....	Nos. 11–12, fig. 21.
	7.5 to .0	1,660	34	30	Nos. 12–13, fig. 21.
5	7.0 to .0	....	70	[e] 40	No. 1, fig. 22.
	0.0 to 6.0	....	17	8	No. 2, fig. 22.
	6.8 to 5.2	....	6	....	No. 3, fig. 22.
					No. 4, fig. 22.[c]

EFFECTS OF CHANGES OF OPERATING CONDITIONS.[f]

Instrument No.	Temperature.			Draft.			Speed.		
	Temperature change.	Change in CO_2 indication.	For graphic record, see—	Water-draft change.	Change in CO_2 indication.	For graphic record, see—	Speed change.	Change in CO_2 indication.	For graphic record, see—
	°F.	*Per ct.*		*Inches.*	*Per ct.*		*Records per hour.*	*Per ct.*	
1	98 to 75	None.	....	0.0 to 1½	None.	....	18 to 4	None.	....
2	98 to 75	+1.0	Nos. 9 and 10, fig. 19.	½ to 0.0	−0.5	No. 13, fig. 19.	16 to 8	+0.5 to +1.3	Nos. 11 and 12, fig. 19.
				0.0 to 1½	+1.5	Nos. 5 and 6, fig. 19.			
3	98 to 75	−1.0	Nos. 4 and 6, fig. 20.	0.0 to 1½	None.	....	48 to 12	0.0 to −0.5	Nos. 4 and 5, fig. 20.
							Revolutions per minute.		
4	81 to 89[g]	....	No. 10, fig. 21.	⅞ to ⅜	−0.7	Nos. 1 and 2, fig. 21.	1,660 to 2,000	+3.3	Nos. 4 and 6, fig. 21.
	79 to 84[h]	+1.4	....	⅞ to 1⅜	+1.4	Nos. 1 to 3, fig. 21.	1,660 to 1,920	+2.8	Nos. 4 and 5, fig. 21.
5	98 to 75	[i] +0.2	No. 5, fig. 22.	0.0 to 1½	None.	....	....	....	....

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[a] With regard to statements as to lag and limits of accuracy, it should be borne in mind that the fundamental standard used as a basis of comparison was the analysis as made in the chemical laboratory, which in itself may have been in error 0.2 per cent.

[b] Determined by admitting the gas directly to the instrument proper (see p. 41).

[c] Shows general form of lag curve when gas is drawn through filter.

[d] Refers to speed of the two centrifugal fans.

[e] The time taken to drop the last per cent when approaching zero varied greatly, whereas to drop to about 1 per cent required only about 10 minutes.

[f] Charts obtained under normal operating conditions are shown in figures 23 to 25 and Plate I.

[g] At fan.

[h] At filter.

[i] Then dropped to −0.3 per cent.

SUMMARY OF RESULTS AND CONCLUSIONS FOR EACH INS MENT.

INSTRUMENT 1.

Instrument 1 had a lag[a] averaging 28 minutes for an indic to the nearest 0.5 per cent, whereas, on the average, 38 minutes required for the instrument to complete its record of the ch Evidence of a change in co sition began to show at abou second analysis, or about 5 mi after the change occurred. V operating at 23 records per the instrument drew a samp 1.73 cubic feet of gas per It could be regulated to rec maximum of about 30 analyse hour. As long as the instru was kept in proper adjust the maximum error for any analysis, when the instrument operating on gas whose com tion was not changing, was per cent CO_2. Its accuracy not affected by change of roo temperature, boiler draft, or num ber of records per hour. The absorp tion chamber contains as the reagent slaked lime, which is distributed through loosely packed excelsior in a jar. Proper packing of a jar required from 30 to 45 minutes. The time that one of these charges will last can not be closely estimated owing to the difficulty of packing two jars exactly alike. This time varied from 555 to 1,194 per cent hours,[b] averaging 740 per cent hours. In order to ascertain whether the reagent was still active it would be necessary to make a check analysis with some other apparatus. This can not be conveniently done unless there is available a gasometer or other vessel to hold a quantity of gas of known composition. It is therefore advisable to change the reagent about as often as recommended. The ordinary daily attention required about

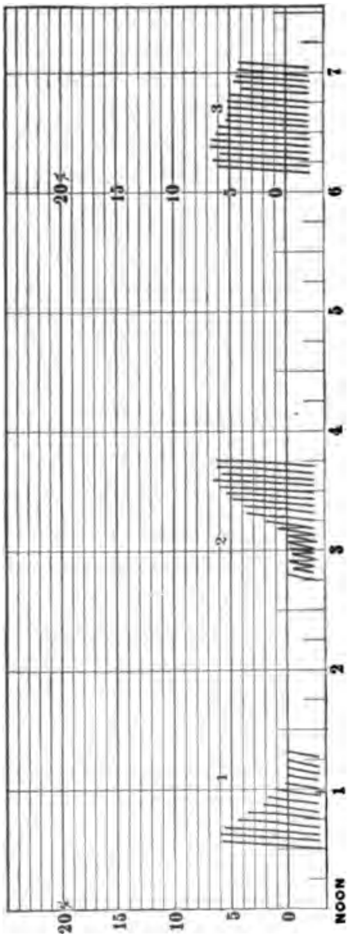

FIGURE 18.—Graphic record from instrument 1, special test. Horizontal lines indicate percentages of CO_2. Vertical lines indicate 1-hour periods.

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[a] Defined on p. 37.

[b] Defined on p. 38.

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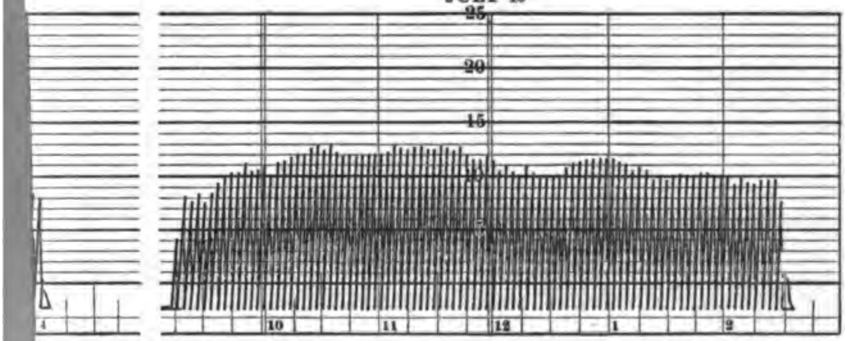

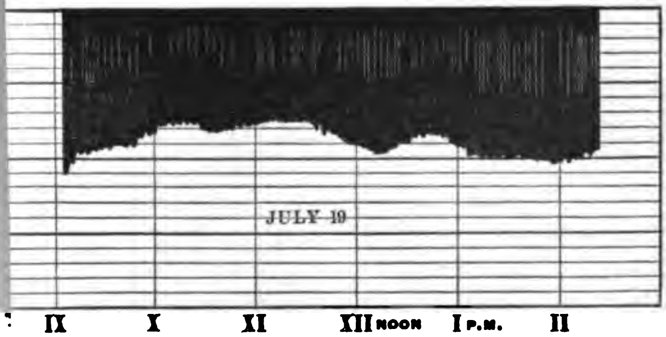

five minutes of a fireman's time. The pen gave considerable trouble and wore out in less than a year. The water piping in this instrument is liable to clog frequently if dirty water is used.

INSTRUMENT 2.

Instrument 2 had a lag averaging 23 minutes for an indication to the nearest 0.5 per cent, and on the average 34 minutes was required for the instrument to complete its record of the change. Evidence of a change in composition began to show at about the second analysis. When operating at the rate of 16 to 17 records per hour the instrument drew a sample of 0.6 cubic foot of gas per hour. It could be regulated to record a maximum of 16 or 17 records per hour. As long as the instrument was kept in proper adjustment the error for any given analysis when the instrument was operating on gas whose composition was not changing was ±0.1 to ±0.2 per cent CO_2, which is about as close as the chart can be read. The accuracy of the device was affected by change of room temperature, draft, and the number of records per hour as shown in the table on page 43. The greatest source of error was the persistent leaking of gas through the joint between the caustic potash (KOH) tank and its cover. The leak was stopped repeatedly by painting the joint with asphaltum paint,

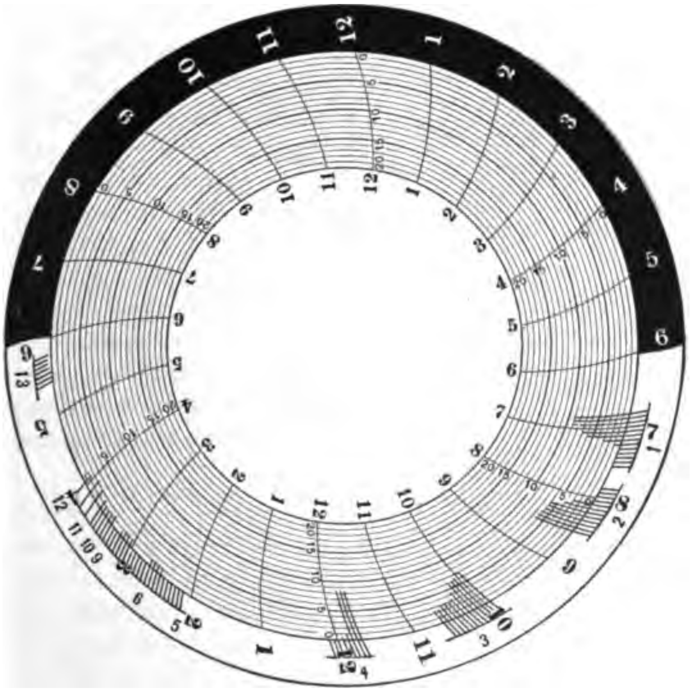

FIGURE 19.—Graphic record from instrument 2, special test.

but the caustic would open a hole again after a time. The reagent—a solution of caustic potash (KOH) in water with a specific gravity of 1.27—lasted about 5,100 per cent hours. To change a solution required about 15 minutes. The time that one of these changes will last can be fairly well estimated. In order to ascertain exactly when a charge has been entirely used it would be necessary to make a check analysis with some other apparatus. This can not be conveniently done unless there is available a gasometer or other vessel to hold a quantity of gas of known composition. It is therefore advisable to change the reagent about as often as recommended. The ordinary daily attention required about 8 to 10 minutes of a fireman's time. Considerably difficulty was experienced in regulating the continuous water supply to maintain the proper water levels, and the use of this part of the apparatus was abandoned.

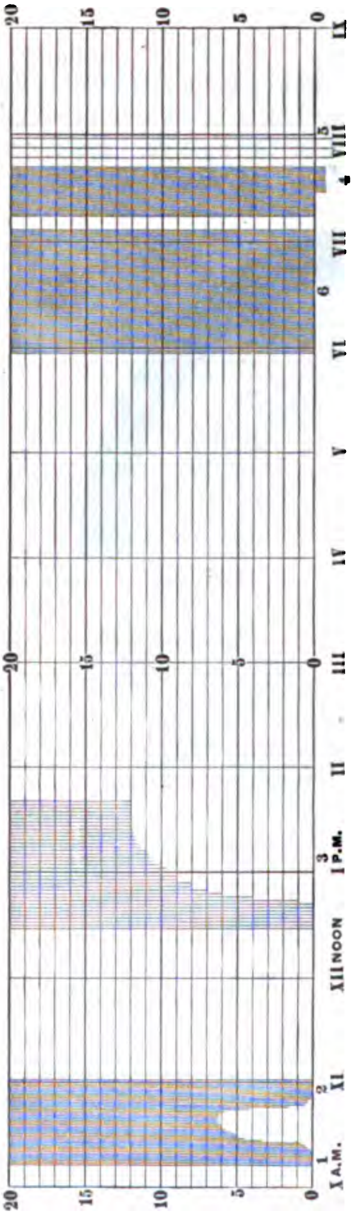

FIGURE 20.—Graphic record from instrument 3, special test.

INSTRUMENT 3.

As instrument 3 has no device with which to draw the gas sample from the sampling tube through the gas line and filter, its lag would depend on the outside means used in drawing in the sample. The part of the lag due to the instrument proper and exclusive of that due to the gas line and filter averaged 9 minutes for an indication to the nearest 0.5 per cent and 12 minutes for a completed record of the change. Obviously these figures can not be compared with those for the other instruments, which include the filter and gas line. Evidence of change in composition began to show at about the second analysis after the change. The instrument could be regulated to record a maximum of about 50 analyses per hour, although 30 is suggested for regular operation. As long as the instrument was kept in proper adjustment the maximum error for any given analysis when the instrument was testing gas whose composition was not changing was ±0.4 per cent CO_2. Its accuracy was not affected by change of boiler draft, but was affected by change of room temperature and the number of records per hour. The reagent—a solution of caustic potash in water, specific gravity 1.27—lasted 2,260 to 2,490 per cent hours, averaging 2,375 per cent hours. To change a solution required about 5 minutes. The time that one of these charges will last can be fairly well estimated. In order to ascertain exactly when a charge has been entirely used, it would be necessary to make a check analysis with some other apparatus, as previously explained. Instead of attempting this it is advisable to change the reagent about as often as recommended. The ordinary daily attention required about 8 to 10 minutes of a fireman's time. Considerable trouble was experienced with the nib type of pen on account of clogging. The rubber connections lasted 12 months or more, with the exception of that under the caustic potash tank, which lasted about 2 months. These parts are readily replaced.

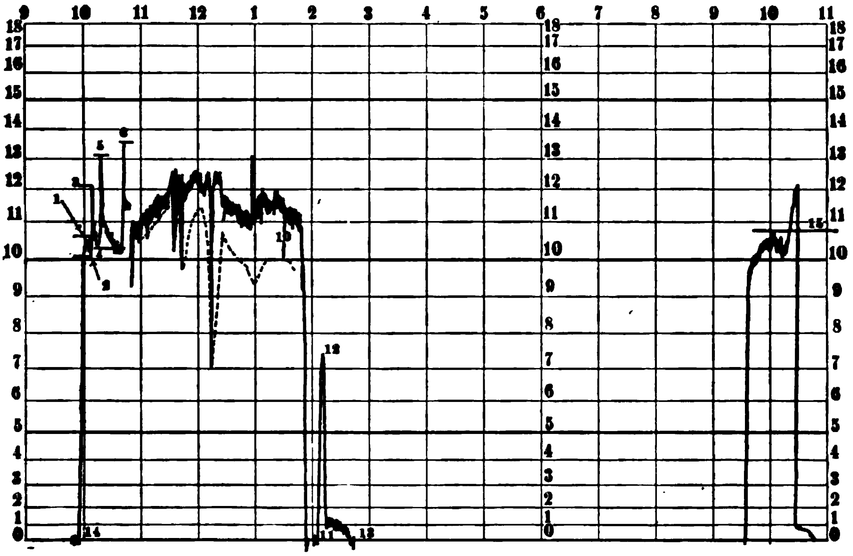

FIGURE 21.—Graphic record from instrument 4, special test. Dotted line represents the record of another recorder plotted here for comparison.

INSTRUMENT 4.

When a gas of higher CO_2 content than had been running to the sampling tube was admitted, instrument 4 had a lag of about 6 minutes for an indication to the nearest 0.5 per cent and of about 8 minutes for a completed record of the change. When a gas of lower CO_2 content was admitted, the lag for an analysis to the nearest 1 per cent was about 5 minutes, and to the nearest 0.5 per cent the lag was about 30 minutes; about 34 minutes was required for a completed record. Evidence of a change in composition began to show practically at once. Under normal working conditions it drew a sample of 2.4 cubic feet of gas per hour. As long as the instrument was kept in proper adjustment the maximum error when the instrument was sampling gas whose composition was not changing was about ±0.2 per cent CO_2, which was about as close as the chart could be read. Accuracy is affected by changes of room temperature, boiler draft, and speed of fan. The instrument makes use of no reagent and hence requires no attention in this respect.

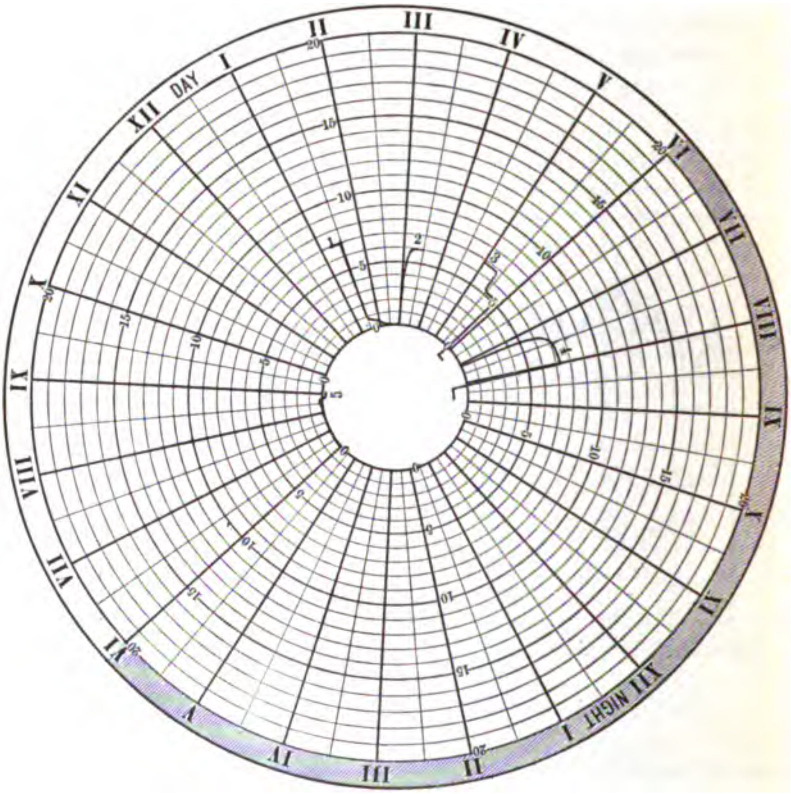

FIGURE 22.—Graphic record from instrument 5, special test.

INSTRUMENT 5.

The lag of this machine was about 5 to 8 minutes for an indication to the nearest 0.5 per cent, except when a gas containing no CO_2 was admitted to the sampling tube. The time required for a complete record of the change varied as shown in the table on page 43. Evidence of a change in composition began to show practically at once. The instrument gave a continuous indication and record of CO_2 content. As long as the instrument was kept in proper adjustment the maximum error when operating on gas whose composition was not changing was about ±0.1 per cent CO_2, which was about as close as the indicator could be read. Its accuracy was affected slightly by change of room temperature but not by change of boiler draft. The reagent is sodium hydroxide (NaOH) packed in pasteboard cartons that fit in a case on the instrument. The cartons are obtained from the manufacturer packed and ready for use in the instrument. They lasted 500 to 1,185 per cent hours, averaging 870 per cent hours. For practical purposes the condition of the reagent and the time when it should be replaced are readily ascertained while the recorder is in operation by locating with the hand the position of the hottest zone on the carton case; when the hot zone is near the top the carton nears exhaustion. In order to determine exactly when a charge has been entirely used, it would be necessary to make a check analysis with some other apparatus. Inasmuch as this can not be readily done, it

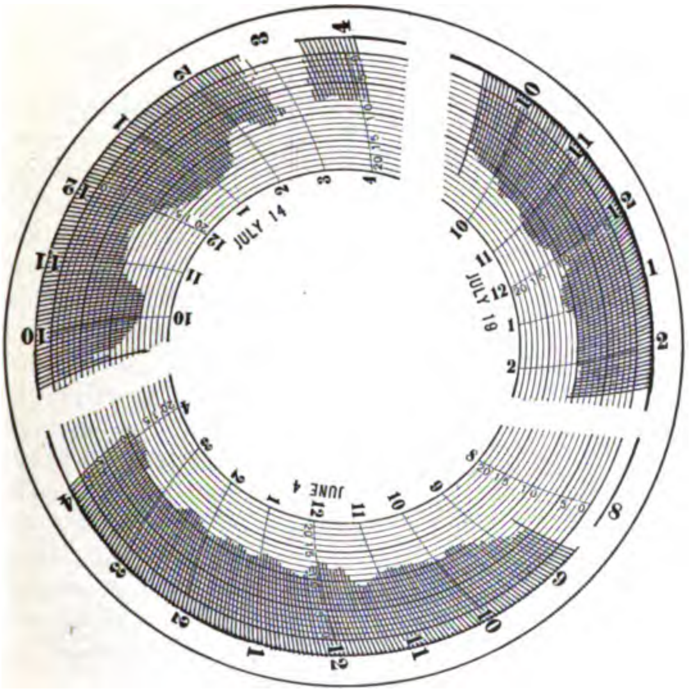

FIGURE 23.—Graphic record from instrument 2, normal operation. The failure of the instrument to record during the 3 o'clock period on July 14 was due to the curling of the chart.

is advisable to be governed by either the per cent hours or the location of the heated zone in changing cartons. The ordinary daily attention required about 8 or 10 minutes of a fireman's time.

This machine has a boiler-room indicator in addition to the chart record and to the indicator on the instrument proper. The boiler-room indicator may be placed on the boiler front or in any convenient place in the boiler room, and need not be close to the recorder.

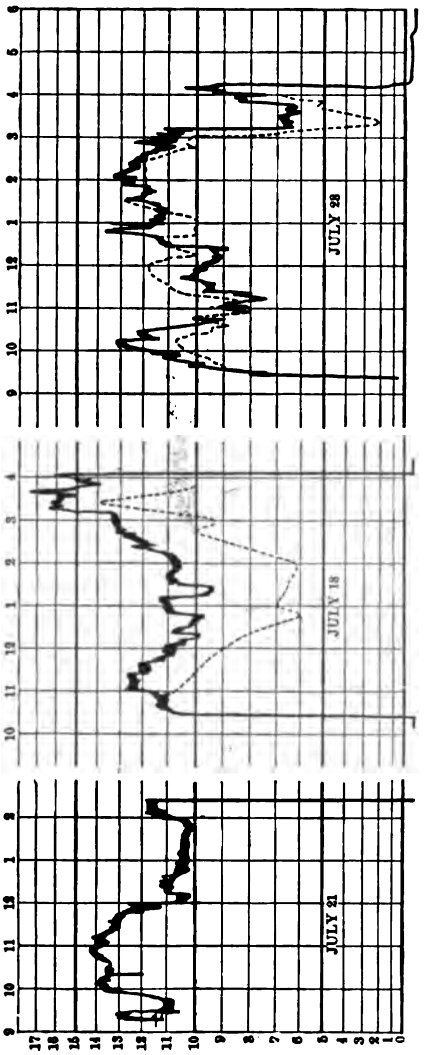

FIGURE 24.—Graphic record from instrument 4, normal operation. Dotted line shows true CO_2 content.

INSTRUMENT 6.

A maximum of about six analyses per hour can be made with this instrument when operated according to directions. By artificially cooling its indicating thermometer immediately following an analysis the number can be increased. With careful manipulation, analyses can be made with a maximum error of ±0.3 per cent CO_2.

The reagent is sodium hydroxide (NaOH) packed in small brass cartridges, one of which must be used for each analysis. The instrument is portable, compact, and convenient.

INSTRUMENT 7.

Seventeen to twenty analyses per hour can be made with instrument 7. With ordinary care an analysis can be made with a maximum error of ±0.2 per cent CO_2. The reagent is a solution of potassium hydroxide in water. Several hundred analyses can be made with one charge of the caustic. The trouble most likely to be experienced is the sticking of the glass cock, owing to the action of the caustic. The device is compact and portable.

HINTS AS TO INSTALLING GAS LINE FOR ANY INSTRUMENT.

For the sampling pipe and gas line of any CO_2 recorder it is well to use three-fourths-inch pipe. A satisfactory way of arranging the pipe is to plug the end inserted into the boiler pass and drill small holes (one-eighth to three-sixteenths inch in diameter) every few inches in a line on one side of the pipe. The pipe is placed clear across the pass, at a convenient point in the gas travel, the small holes in the pipe being at right angles to the flow. The sampling pipe must be used at a place where the flue gases have become well mixed. Generally this can be found near the damper on the boiler side. Sluggish pockets of gas should be avoided.

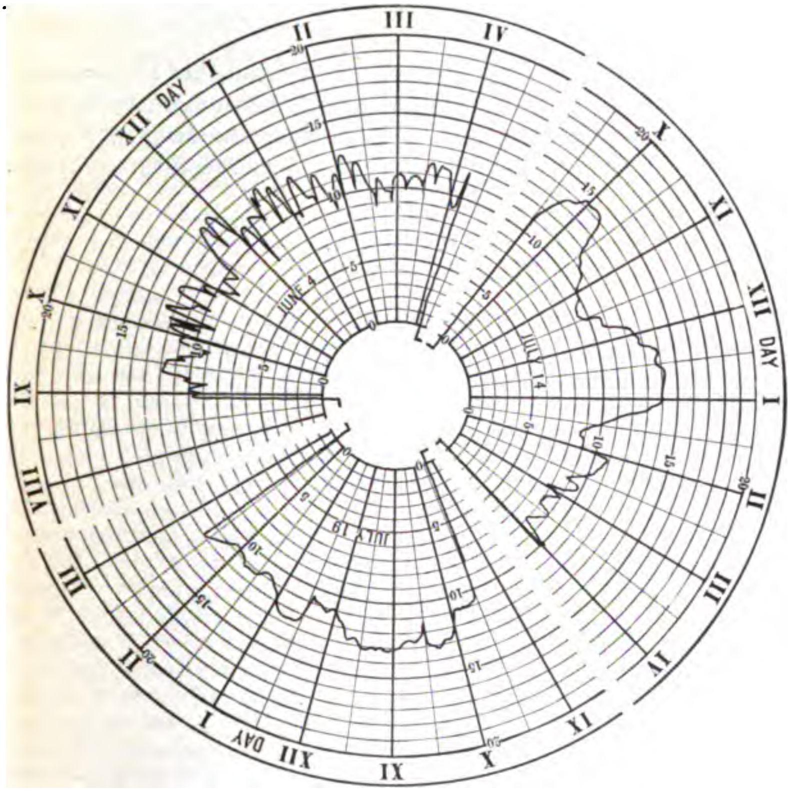

FIGURE 25.—Graphic record from instrument 5, normal operation.

All turns in the gas line should be made with crosses instead of elbows, the extra openings of the crosses being plugged. This plan allows the line to be easily cleaned. In running a gas line from the boiler to the filter and from the filter to the instrument proper, great care must be taken to insure a tight line so that the gas can not become mixed with outside air. Asphaltum paint should be used in the joints and should be applied to the entire line after it has been connected. There should be a slight fall in the line toward the recorder, and sagging pockets should be avoided. Just in front of the instrument a vertical drop pipe should tap the pipe line. A small drain cock should be placed at the end of the drop pipe. Water can then accumulate in the drop pipe and be let out from time to time. The entire line should be so arranged that it can be blown out, preferably by compressed air or by steam. Each of the recorders has a manometer arrangement to show when the line becomes clogged to such an extent that blowing out is necessary.

Although the maker's instructions recommend that for each instrument the filter be as near as possible to the sampling tube, it may, under some conditions, be advisable to place the filter at a point in the sampling line near to the recorder in order to facilitate proper care of the filter.

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DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
BUREAU OF MINES
VAN. H. MANNING, DIRECTOR

THE FELDSPARS OF THE NEW ENGLAND AND NORTH APPALACHIAN STATES

BY

A. S. WATTS

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THE FELDSPARS OF THE NEW ENGLAND AND NORTH APPALACHIAN STATES.

By A. S. Watts.

INTRODUCTION.

The Bureau of Mines has been conducting an investigation of the feldspar resources of the New England and North Appalachian States with a view to greater efficiency and economy in their utilization. Such an investigation was deemed necessary, not only because of the continued and increasing consumption of these minerals, but especially because of the demand for better technical control of the raw materials that are used by the white-ware industries of the United States. Most manufacturers of white pottery wares have only a limited knowledge of the origin, mode of occurrence, and methods of mining and preparation of the materials that they use.

Heretofore, owing to a belief that the supply of raw material was unlimited, the manufacturer had concerned himself chiefly with the solution of the problems of manufacture. Within the past few years, however, it has been found that difficulties arise in manufacture which can be traced beyond the manufacturing process and are believed to be due to a need of better control of the materials used.

Furthermore, as competition becomes more severe, more attention must be paid to selection of materials in order to minimize consumption and also to avoid unnecessary expense for transportation of material.

Doubtless the lack of interest as regards these details has arisen from the fact that in the past a considerable proportion of the white-ware ingredients has been imported and the manufacturer has been forced to rely on the samples submitted and the general uniformity of the source of supply to insure against variation of the material. An extra precaution arising from this lack of definite knowledge still prevails in the common practice of never depending on one source of supply for any one ingredient. Often the products of three or more producers are blended so that if any one shall vary without warning the variation arising from its use will not be sufficient to ruin the ware.

As the use of domestic materials has increased, the manufacturer has generally depended on the results of tests of samples submitted. The crude materials differ so greatly from the materials purchased, and the treatment necessary to prepare crude material for use involves such an intimate acquaintance with its peculiarities that the users had further cause to neglect to acquaint themselves with the details of its mining and preparation.

The investigations presented in this bulletin have been undertaken by the bureau with a view to a better understanding of the conditions which confront the producer of commercial feldspar and also with the object of determining wherein the various deposits of feldspar differ. This information will enable the manufacturer to choose the source of supply which is best suited to his needs, and in case a change is necessary to choose more intelligently the location from which to draw for his future supply.

FELDSPAR—AVAILABILITY, GRADES, AND USES.

Feldspars are by far the most abundant of all the minerals and are estimated to constitute nearly 60 per cent of the igneous rocks.[a]

However, of the feldspar having commercial value a large proportion is so intimately mixed with other minerals that recovery in the pure state would be very expensive if not impossible. The deposits yielding commercial feldspar are made up of a great variety of mineral combinations and occur in all grades as regards coarseness of crystallization. The deposits are widely distributed, and many of them are so far from railroads as to make mining impracticable.

At present there are at least 15 districts in the eastern part of the United States from which a commercial grade of feldspar is obtainable. Nevertheless, in the relatively short time that the supply of feldspar in the United States has been drawn on, the high-grade material has been almost totally exhausted in some districts and seriously depleted in several other districts. Conservation of these resources demands that cognizance of these facts be taken, and, if unnecessary wastefulness has occurred in the past, that steps be taken to correct the errors. It is vitally important that the material best suited be provided for the various industries and that a material available only in limited quantity shall not be employed in an industry which can use equally well a slightly inferior material which is available in greater quantity.

The chief users of feldspar are the manufacturers of white pottery ware. The manufacturers of glass and enameled metal wares are also extensive users of feldspars. The scouring-soap industry uses a limited amount, but careful selection as to color does not apply to the feldspar used in making soap. An enormous amount is annually consumed in the manufacture of roofing and for poultry grit, but these products do not require a material free from impurities and in most instances a low-grade feldspar is used. Pulverized feldspars of the potash varieties are also used as ingredients in some fertilizers and for this use the presence of iron-bearing impurities is not detrimental.

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[a] Clarke, F. W., Analyses of rocks from the laboratory of the United States Geological Survey: U. S. Geol. Survey Bull. 228, 1904, p. 20.

Although the above and many other uses have been found for feldspars of the different grades, it is a noteworthy fact that in few districts is a feldspar deposit being worked for more than one or at most two grades. If the deposit is opened for a pottery feldspar, the grades of feldspar not suited for this use are either not removed in the mining or if the nature of the deposit makes their removal a necessity they are thrown on the dump and there mixed with overburden and other refuse and their recovery at a later date would be more expensive than original mining. If the quarry is opened for a low-grade feldspar, the entire deposit suited for this use is mixed and sold for this purpose, no attempt being made to separate the high-grade feldspar that might be marketed for special purposes. The few attempts made in the past to select the feldspar into grades met with discouragement because the supply of choice feldspar was then so great that no special demand existed for pure feldspars. In recent years some of the older and more extensive deposits of pottery feldspar have become depleted of their choice feldspar and it has become a common practice to obtain pure feldspar in limited quantity from a new quarry and blend this with the output of the old one to make a marketable product, thus prolonging the life of the quarry as a producer of pottery feldspar.

The deposits from which the choice feldspar is obtained are left in the same condition as the quarries for the improvement of which the choice material is sought. The quarries thus robbed are in most instances small or handicapped by pooi transportation facilities. After the choice feldspar has been removed they are abandoned and often are filled with refuse so that reopening would not in most cases be practicable. If the necessary pure feldspar can be obtained from the quarries now opened and worked for low-grade feldspars, this system of incomplete mining can be largely dispensed with.

That the present demand for a pure feldspar in many of the industries is unwarranted is evidenced by practices both in England and throughout Continental Europe.

The enormous white-ware industries of Staffordshire, England, are dependent upon the coarse granites or pegmatites of Cornwall for their feldspathic material. This district does not produce any pure feldspar, but only material that is a mixture of feldspar and quartz with minor other minerals. The success which has attended the use of this material is indicated by the fact that enormous quantities of crude "Cornwall stone" are annually imported into the United States for manufacturers who find it more satisfactory for their purposes than any of the American feldspars.

In France the supply of feldspar is limited indeed, and the famous wares of Limoges are to-day made from semiweathered pegmatites of the St. Yrieix district. These are crushed and pulverized by wet grinding, and to them are added what additional kaolin and flint is necessary to produce the desired strength for molding and the demanded translucency when fired.

The feldspars of Scandinavia are also in reality pegmatites if one may judge from the analyses obtainable.

The foregoing indicates that deposits of pure feldspar no longer are available for the use of the European manufacturer, and he has found it possible to produce an equally satisfactory ware from a mixture of feldspar and such other minerals as are not actually injurious when the material is properly prepared.

Toward this same condition the American user of feldspar is rapidly approaching and conditions are not improved by ignorance of the gradual change that is occurring or by imagining that the same quality of material is being supplied as was obtained when the deposits were first opened.

As the necessity for substitution becomes apparent, the importance of a more thorough knowledge of the different feldspar producing districts of this country increases.

GENERAL CONDITIONS GOVERNING THE MINING OF FELDSPAR.

In mining feldspar the personal judgment of the operator and his numerous employees regulates the quality of crude material accepted and on the uniformity of this selection the manufacturer depends for the maintenance of the quality of his ware. Fortunately in most of the feldspar quarries the men employed have been trained by long acquaintance with the feldspars of the district, otherwise serious error in selection might easily result. The ordinary process of sorting the feldspar is as follows:

The quarried rock is piled in long rows and then a crew of men provided with light sledges sort the pieces, breaking off the impure parts. By this system, known as "cobbing," the rock is prepared for the mill.

The accepted material is then heaped in an open space, where it is exposed to the weather for a few weeks in order that the rains may carry away any dirt which may be adhering to the broken stone. The length of time allowed for the elements to effect the cleaning of the rock is dependent largely on the urgency of the demand for the crude material. All crude feldspar was formerly subjected to a thorough washing but this practice has been abandoned in recent years. Another cause of serious contamination is surface water containing iron salts which runs down the faces of the quarry and stains the rock. These stains or incrustations on drying adhere so firmly that any ordinary method of cleaning or washing fails to remove them.

ORIGIN, CHARACTER, AND MODE OF OCCURRENCE OF THE FELDSPATHIC ROCKS.

All the feldspar-bearing rocks are of igneous origin—that is, they have solidified from molten masses. The potash and soda feldspars, with which this work deals, are found chiefly in granites, which generally occur as vast intruded masses and consist essentially of quartz, feldspars, micas, and hornblende. Granite masses generally contain bodies of rock that is similar in composition to the granite itself but was intruded after the latter had more or less solidified. These intrusions are named according to the angle of their dip; those nearly vertical are called dikes and those more nearly horizontal are called sills.

These dikes or sills are generally pegmatite—that is, they are coarsely crystalline granite in which feldspar and quartz are the chief constituents; the other granite constituents may be totally absent or replaced by rare minerals. This pegmatite is the source of supply of the feldspar of commerce.

The character of the pegmatite dikes and sills varies widely. In some dikes the rock is of a comparatively uniform texture throughout and its contact with the granite walls which inclose it may be indistinct, indicating more or less blending of the two at the time of intrusion. Other dikes consist of a number of distinct and separate bands of rock of widely differing composition, indicating several distinct periods in the process of solidification.

When the crystallization is very coarse or the constituents of the dike are separated into distinct bands it is sometimes possible to obtain feldspar in commercial quantity absolutely free from associate minerals. In most dikes the feldspar and quartz are crystallized too intimately to permit of such a separation and the most that can be accomplished is the elimination of such associated minerals as are segregated or sufficiently coarsely crystalline.

The origin of pegmatite intrusions has been explained in various ways, but they are generally conceded to be of the same general mass as the original granite and to have been intruded into openings formed by eruptions of gases and vapors or by cracking of the crust of the granite mass on cooling. Often these crevices or ruptures extend beyond the granite mass and thus pegmatite dikes are often found extending through several different types of surface rock.

The shape of the dike is always lenticular, as would be expected of a mass intruded under greatly varying pressure into a mass of widely differing density. As the form of cooling cracks in a mass of solidifying granite would naturally vary in direction and width, the extent and directions of the pegmatite mass are very irregular, a zone of easily ruptured granite resulting in an expanded lens of pegmatite which may abruptly pinch out or be reduced to a mere stringer that at an uncertain distance expands again to a lens.

The structure of such a deposit is as variable as the dimensions. A pegmatite dike may abruptly change from a coarsely crystalline mass, practically free from any minerals except feldspar and quartz, to a finely crystalline mixture containing amounts of associate minerals which render it valueless as a source of commercial feldspar. Bodies of rock similar in composition to the wall rock are often found completely inclosed within the dike. These bodies or horses are most frequently found in the larger lenses and generally have sharply defined outlines, so that if reasonable care is exercised in mining no contamination of the feldspar need result from their presence.

This uncertainty in the continuity and uniformity of all pegmatite dikes must be taken into consideration in the development of any such deposit. Only by the most thorough preliminary prospecting and sampling can the operator be insured against failure through the sudden alteration or pinching out of the deposit.

A peculiarity of many dikes is the occurrence of remarkably clean pegmatite in considerable quantity in the upper part of the dike, whereas at a depth of 10 to 15 feet the different iron-bearing minerals begin, and the dike rapidly changes to a coarse biotite or hornblende granite and at greater depths to a fine-grained granite, which, however, is rarely of such quality as to be of any value. This form of structure has been the cause of much trouble where only surface samples have been taken before quarrying was begun. Surface areas of clean pegmatite underlaid by impure material are rarely of great extent and were it not for the fact that they often extend across the entire width of the dike could be easily detected and classified as lenses in the dike. Along the strike of the dike in both directions the dike material gradually changes to impure coarse granite, so that a proper survey would have warned the prospector of the uncertainty of the clean pegmatite continuing with depth.

The presence of a capping carrying a high content of biotite and garnets and so mixed with impurities as to condemn it as a possible source of feldspar has led many prospectors to ignore dikes which contain, below the surface, pegmatite of a quality equal or superior to much that is now being marketed. These cappings are sometimes only a few inches thick, but generally average 1 to 2 feet thick, and the removal of 1 or 2 additional feet of rock is often necessary before pegmatite of a marketable grade is reached.

The evidence of incomplete prospecting is everywhere apparent in the districts investigated by the bureau, and many valuable deposits have doubtless been overlooked by such practices.

THE FELDSPAR DISTRICTS OF THE NEW ENGLAND AND NORTH APPALACHIAN STATES.

MAINE.

In Maine there are at least three distinct districts where feldspar-bearing rocks exist in commercial quantity and several minor centers which are worthy of more thorough prospecting than the scope of this investigation has permitted. The most eastern point at which a commercial grade of feldspar is found in this State is at East Orland, Hancock County, where dikes of a medium-grade microcline pegmatite protrude in many places several feet above the surrounding country. The dikes are generally only a few feet thick and the exposed parts have weathered on their surfaces to a mass of sand (Pl. I, *A*), in which the quartz grains and the feldspar particles have been separated by the weathering, but below the surface the dikes seem solid and are comparatively free from the injurious impurities of most pegmatites. Inaccessibility is the only drawback to the working of these dikes.

BOOTHLAY DISTRICT.

One of the most important feldspar districts of the United States is the Boothlay district, which extends from Boothlay on the Atlantic coast to Mount Ararat, north of Brunswick, and embraces Sagadahoc County and the eastern part of Cumberland County. The feldspar of this district is a mixture of coarse microcline pegmatite and large masses of graphic granite. The dikes vary greatly as regards impurity. In the northern parts of the district the dike rock contains large lath-like crystals of biotite, the most common impurity in Maine feldspar, but in many deposits along the coast that mineral is largely replaced by black tourmaline. Albite in very limited quantity is finely intergrown with the pegmatite. The feldspar of this district is pale cream in color, the quartz in the pegmatites is clear or of the light shades of the smoky variety. Very little massive sugar quartz is found in this district. Beryl, mostly of the opaque variety which yields no gem material, is not uncommon in the dikes along the coast. The muscovite is ruled and yields little sheet mica.

MOUNT APATITE DISTRICT.

The Mount Apatite district extends west and southwest from Mount Apatite, Androscoggin County. The feldspar occurs almost entirely as isolated pegmatite lenses, which lack uniformity both as regards strike and dip. Albite pegmatite is associated with the microcline pegmatite in some deposits and is also found entirely separate. Lenses of practically pure milk-white albite are also present in a few dikes. These lenses are generally small and not capable of supplying any great part of the present demand for soda feldspar. One of the drawbacks to mining this soda feldspar is the fact that it is chiefly of the lamellar variety cleavelandite, which has a pronounced cleavage and breaks into small particles on handling, thus rendering it especially liable to contamination from surface material and associated impurities in the dike. The potash feldspar is a buff-colored microcline pegmatite of coarse crystallization, intergrown with small amounts of albite. Biotite is present in all the microcline pegmatite deposits and muscovite in sufficient quantity in a few deposits to justify its utilization for small punch mica.

The discovery of gem-bearing pockets in the pegmatite of this district has encouraged the working of many small dikes and much valuable feldspar has been obtained as a result. The chief gem mineral sought is tourmaline, which usually occurs inclosed in pockets of albite.

MOUNT MICA DISTRICT.

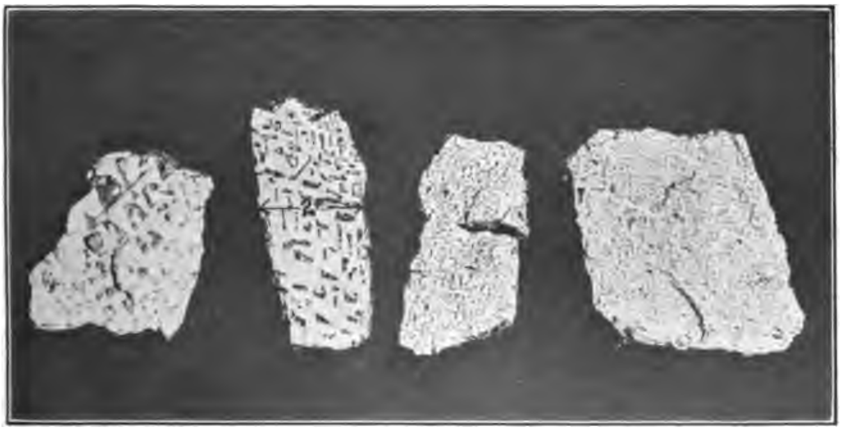
The Mount Mica district is situated in Oxford County with Mount Mica as a center. There are two distinct types of feldspar-bearing formations in this district: (*a*) Sharply defined microcline-pegmatite dikes standing almost vertical and having definite strike; and (*b*) irregular lenticular deposits of microcline pegmatite and albite containing pockets of gem minerals.

The sharply defined dikes are generally free from any detrimental impurities, except black tourmaline and biotite, and these are rarely associated in the same dike. Garnets are present in a few of these dikes, but rarely in sufficient quantity to seriously injure the product. Muscovite occurs in most of these dikes, and, as a rule, is confined to limited zones, which permits of its easy removal in mining, or is sufficiently coarsely crystalline to permit of its elimination by "cobbing."

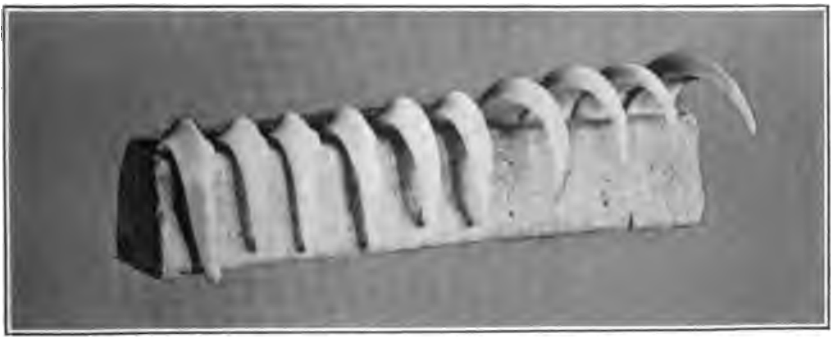
The feldspar of these deposits is a pale buff to pale cream microcline. The associate quartz is chiefly of the smoky variety, being almost black in some deposits near Mount Rubellite, in the eastern part of this district. Massive sugar-quartz occurs in many of these dikes, and in the neighborhood of Paris is a fine grade of rose quartz.

The irregular lenses of feldspathic rock which are distributed through this district can hardly be said to constitute a source of feldspar supply because the feldspar is so hopelessly mixed with other

A. WEATHERED PEGMATITE DIKE AT EAST ORLAND, ME.



B. TYPICAL GRAPHIC GRANITES, SHOWING VARIATION IN SIZE OF CRYSTALS.



C. APPEARANCE OF CONES AFTER DEFORMATION.

minerals that no miner would attempt to work the lenses for their feldspar alone. In the search for gems, which are found chiefly in this type of formation, much feldspar has been exposed and from time to time this has been removed and has added considerably to the feldspar production of the district. The feldspar of these deposits is a pale buff microcline and a milk-white albite.

OTHER DEPOSITS.

There are many small dikes of pegmatite in the State of Maine, which are not included in these districts, but they do not differ materially from the feldspars recorded. Throughout the State of Maine a remarkable uniformity prevails both in the potash and the soda feldspars.

ANALYSES OF MAINE FELDSPARS.

Samples of potash feldspar taken from various deposits, from south to north across the State, show the following analyses:

Analyses of potash feldspars of Maine.

[A. C. Fieldner, analyst.]

Constituent.	A	B	C	D	E
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	64.67	64.90	65.07	64.97	65.48
Al_2O_3	19.18	19.75	19.39	19.48	19.39
Fe_2O_3	.20	.12	.10	.04	.08
CaO	.99	....	Trace.	....	....
MgO	Trace.	Trace.	Trace.	Trace.	Trace.
Na_2O	2.54	2.68	2.52	2.56	2.85
K_2O	12.76	12.04	12.58	11.76	11.51

These potash feldspars have a deformation range of 1,275° C. to about 1,295° C. (cone 7+ to cone 8+). They fuse to a transparent glass practically free from color.

The soda feldspars of the Mount Apatite district show the following compositions:

Analyses of soda feldspars from Mount Apatite district.

[A. C. Fieldner, analyst.]

Constituent.	Albite.	Albite pegmatite.
	Per cent.	*Per cent.*
SiO_2	66.36	71.55
Al_2O_3	21.35	18.11
Fe_2O_3	.12	.16
CaO	1.10	.46
MgO	.21	Trace.
Na_2O	9.74	8.72
K_2O	.73	.64

These soda feldspars have a deformation range of 1,270° C. to about 1,275° C. (cone 7 to cone 7+).

NEW HAMPSHIRE.

The pegmatite of New Hampshire has never been quarried for its feldspar content, but a quarry near North Groton, Groton County, has been opened for mica, and the feldspar of this deposit is similar to the Maine feldspar as regards physical properties and pyrometric behavior. No analysis is available.

MASSACHUSETTS.

An irregular dike of pegmatite containing many lenses of pure feldspar has been opened near Blandford, Hampden County, Mass. This deposit consists of a cream-colored feldspar, coarsely crystalline, associated with a clear or slightly smoky quartz. Optical and pyrometric tests indicate that it is a feldspar high in potash and low in soda. As no similar dikes are exposed in the vicinity of the quarry, and it had been abandoned on account of the expense of hauling to the railroad, which is 4 miles distant at Russell, Mass., this feldspar was not analyzed. A careful survey of this district would doubtless result in the discovery of other deposits of potash feldspar of equally high quality.

CONNECTICUT.

The feldspar-bearing pegmatites of Connecticut are situated along the banks of the Connecticut River in Hartford and Middlesex Counties, for a distance of about 20 miles. The center of this district is Middletown, and the feldspar deposits north of this point are confined to the east side of the river, whereas south of Middletown the deposits are found on both sides of the river.

The feldspars are constituents of coarse pegmatites which occur as well defined dikes of varying size and having a general northeast strike. The pegmatites of Connecticut are more free from associate minerals than those of Maine, but in structure and color the pegmatites of these two States are remarkably similar. Small lenses of albite or albite pegmatite are perhaps more common in Connecticut and the quartz content of the dikes is undoubtedly slightly higher than in Maine, but the method of handling the quarried product will control, to a great extent, the content of both these minerals in the marketed product. The amount and mode of occurrence of black tourmaline and biotite are about the same as in the Maine deposits, muscovite is perhaps slightly less prevalent but occurs in a finer state of subdivision. Garnets are rarely present and then only in negligible quantity; beryl is rarely found in quantity.

The general uniformity of the potash feldspars occurring in pegmatite in Connecticut is shown in the following analyses of samples taken from different parts of the district:

Analyses of Connecticut potash feldspars.

[A. C. Fieldner, analyst.]

Constituent.	A.	B.	C.
	Per cent.	*Per cent.*	*Per cent.*
SiO_2	64.65	65.24	66.02
Al_2O_3	19.10	19.74	18.99
Fe_2O_3	.14	.12	.08
CaO	Trace.	None.	None.
MgO	Trace.	None.	None.
Na_2O	2.32	3.04	3.12
K_2O	12.58	11.84	10.96

These feldspars have a deformation range of 1,275° C. to 1,290° C. (cone 7 + to cone 8). They are pale buff to pale cream and fuse to a practically colorless transparent glass.

Soda feldspar does not exist in commercial quantity in Connecticut, but a limited amount could be obtained by careful selection in handling the crude rock from the different quarries, as it generally occurs as small well-defined lenses in the pegmatite, and also as perthitic intergrowths in most of the microclines.

NEW YORK.

The feldspars of New York vary widely and do not in any respect resemble the feldspars of New England deposits.

The nature of the deposits, the mode of occurrence, and the general location divide the feldspar-bearing deposits of New York into three districts: The Ticonderoga, the Batchellerville, and the Westchester.

TICONDEROGA DISTRICT.

The Ticonderoga district includes the territory about Crown Point and Ticonderoga, Essex County. The feldspar of this district consists of a coarsely crystalline mixture of pearl gray microcline and sea-green plagioclase, the greater part being plagioclase, and contains much less quartz than the New England pegmatite. Biotite is the chief associated impurity and large quantities in the form of "books" are scattered throughout the entire deposit. It is extremely brittle and its removal by cobbing would be difficult. Calcite is intimately crystallized with the microcline in some deposits and its removal by cobbing would be almost impossible. The microcline has a highly developed cleavage and generally breaks into small cubelike fragments on the least blow, which adds to the difficulty of removing this material in an uncontaminated state. The plagioclase has no pronounced cleavage and breaks with more or less conchoidal fracture. It is opaque and has a vitreous luster. It contains from 0.50 to 0.60 per cent of iron oxide, although its color when fused would indicate a much higher iron content. It deforms at a temperature of 1,450° C. (cone 16) and would harden a potash-soda feldspar and hence, even if it were colorless, would be an injurious admixture. The microclines of this district are quite uniform in composition with the exception of the alkali content, which is slightly variable, as is apparent by the deformation temperatures of the feldspars.

The feldspathic dikes of the section are worked solely for material to be used in the manufacture of prepared roofing and for poultry grit. The presence of the impurities is therefore not of importance. Operators claim that attempts to sort the high-grade feldspar from the bulk of the dike material have not been profitable owing to the small proportion of feldspar of a sufficiently high grade to command a special price, and the greatly increased expense of handling. Small quantities of high-grade feldspar could, however, be obtained merely by selection when quarrying exposes a lense of pure or nearly pure microcline, and this selection should not greatly increase the expense of production, although it might necessitate a slight shift of quarrying operations while the high-grade material was being removed. The dikes of this district are very extensive both as to width and length, and it is to be regretted that the bulk of their contents is so low grade.

BATCHELLERVILLE DISTRICT.

The Batchellerville district is situated in Saratoga and Fulton Counties, its center being near Batchellerville. The feldspar of this district consists largely of a pearl-gray microcline pegmatite similar to that of the Ticonderoga district. The sea-green plagioclase is absent and the only soda feldspar present in independent masses is a few small lenses of a peculiar milk-white plagioclase, carrying about 4.50 per cent CaO and 8.50 per cent Na_2O. The feldspars contain small crystals of biotite, which is present in large amounts only in the capping material. Garnets are found in only one dike and not throughout the full extent of this deposit. Most of these pegmatites contain muscovite. A graphic granite structure was noted at several points in this district. One dike of salmon-colored feldspar occurs within this district and this feldspar was found on analysis to contain 14 per cent K_2O, which accounts for its temperature range of deformation, 1,280° to 1,300° C. The pegmatites have a lower quartz content and a lower average proportion of impurities than the New England pegmatites, and although not as uniform in composition as the New England feldspars the coarsely crystalline structure permits of a more complete elimination of the associate minerals than is possible in New England. The feldspars of this district are famous for their fine color and have been drawn on exclusively for use in raising the quality of the output from semiexhausted quarries in other districts. Lack of railroad facilities has been the chief drawback in the general development of the feldspar deposits of this district.

ANALYSES OF FELDSPARS FROM BATCHELLERVILLE DISTRICT.

Some representative feldspars of this district show the following analyses:

Analyses of feldspars of the Batchellerville district.

[Robert Back, analyst.]

Constituent.	Pearl-gray microcline.	Salmon microcline.	Plagioclase.
	Per cent.	*Per cent.*	*Per cent.*
Ignition loss	0.26	0.17	0.54
SiO_2	65.14	64.26	61.91
Al_2O_3	19.38	18.78	23.69
Fe_2O_3	.29	.43	.40
TiO_2	.01	......	......
CaO	.44	.33	4.37
MgO	.14	.14	.13
BaO	......	......	......
K_2O	11.28	14.15	1.17
Na_2O	3.61	2.01	8.40

WESTCHESTER COUNTY DISTRICT.

The Westchester County district has comparatively narrow limits. It has its center in an enormous pegmatite dike of widely varying structure situated just east of Bedford village and includes numerous smaller dikes or stringers of this main dike, all within a radius of a few miles. The main dike consists of at least four distinct types of feldspar. The eastern part is a pink to salmon microcline almost free from quartz and associated with an albite pegmatite. Small lenses of a chalky white albite free from quartz are scattered through this part of the dike. The crystallization in these three types of feldspar is relatively coarse and their separation on a commercial scale is entirely practical. Biotite is associated with the soda feldspars in some parts of the deposit, but such parts could be easily eliminated in sorting. Many large lenses of sugar quartz occur in this dike.

To the west of the main deposit and at a level about 80 feet below it is an enormous lens of cream and dark buff microcline pegmatite, of much finer crystallization as regards feldspar and quartz, some parts of it being graphic granite. Biotite is associated with the feldspar of this lens, but can be eliminated by cobbing, and hence does not constitute a menace to the mining of the material for pottery feldspars. Albite pegmatite of good quality is also present in this part of the deposit. To the east of the main deposit are several small dikes of cream-colored microcline pegmatite which is coarsely crystalline, contains little albite, much massive sugar quartz, and no graphic granite.

Because of the great variety of feldspars in this district special caution is needed in mining and selection, otherwise a great variation in maturing temperatures and rate of deformation will result. If proper care is exercised, however, the district is capable of producing excellent grades of potash and soda feldspar, although the latter would contain a considerable amount of free quartz. The feldspars of this district have been drawn on in the past chiefly to supply the enamel and glass industries, and no effort has been made to meet the demand of the potter for a finely pulverized product absolutely free from coloring material.

PROPERTIES OF FELDSPARS FROM WESTCHESTER COUNTY DISTRICT.

The microcline both of the salmon and buff varieties fuses to a practically colorless glass and has a deformation range of 1,265° to 1,280° C. The albite pegmatite fuses to a milk white enamel and has a deformation range of 1,265° to 1,270° C., notwithstanding its high quartz content. The representative feldspars of this district show the following analyses:

Analyses of feldspars of Westchester County district.

Constituent.	Salmon microcline.[a]	Buff microcline pegmatite.[b]	Albite pegmatite.[a]
	Per cent.	*Per cent.*	*Per cent.*
Ignition loss	0.22	0.28	0.40
SiO_2	64.82	69.45	73.88
Al_2O_3	18.87	16.76	15.73
Fe_2O_3	.29	.20	.36
TiO_2	.01	None.	.01
CaO	.23	.45	.86
MgO	.16	.05	.36
BaO	Trace.	.10	....
K_2O	13.11	9.80	.48
Na_2O	2.70	2.60	7.97
Total	100.41	99.69	100.05

[a] Robert Back, analyst. [b] D. J. Demorest, analyst.

PENNSYLVANIA.

The only feldspar producing district of Pennsylvania is situated west of Philadelphia in Delaware and Chester Counties, between the Delaware and the Susquehanna Rivers. Most of the quarries are within hauling distance of the Philadelphia, Baltimore & Washington Railroad. One deposit near Pomeroy, on the Pennsylvania Railroad, is also worked, but the output is sold exclusively as poultry grit.

The feldspars of Pennsylvania comprise two forms of microcline pegmatite and two of albite pegmatite. These feldspars have enjoyed excellent reputations for quality, but the large deposits have been exhausted and now operations are confined to smaller dikes and to the resorting of the rejects from the older workings. Not a single quarry in Pennsylvania is producing enough material at the present time (April, 1915) to operate a grinding mill, the products of several small quarries being purchased and delivered to a central mill which blends them.

The microclines of Pennsylvania may be divided into two general classes: (*a*) A buff microcline occurring as a pegmatite of medium coarse crystallization in most dikes, but occasionally occurring as a graphic granite; and (*b*) a salmon microcline occurring as small lenses in the buff pegmatite and in a few instances as the chief microcline constituent of an albite pegmatite dike. These two forms of microcline do not differ widely in composition, as indicated by the following analyses:

Analyses of Pennsylvania microclines.

[D. J. Demorest, analyst.]

Constituent.	Buff microcline.			Salmon microcline.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Ignition loss	0.33	0.30	0.21	0.12
SiO_2	64.40	63.68	64.36	64.70
Al_2O_3	20.22	19.93	20.01	19.60
Fe_2O_3	.06	.20	.20	.03
CaO	.06	.13	.46	.05
Na_2O	2.77	3.00	2.48	3.76
K_2O	12.62	12.22	12.44	11.87

The associate quartz is generally a pale smoky variety. Massive quartz as sugar quartz is less common in the microcline pegmatites of Pennsylvania than in those of New England and New York. Biotite is associated with the microcline in most deposits, but generally not to such an extent as to disqualify the dike material for pottery uses.

Garnets are also present in a few deposits, but are generally confined to limited zones which can be eliminated by careful mining.

All the microcline pegmatites contain muscovite in small flakes but the amount present in this form constitutes so small a percentage of the total mass that its injurious influence need not be considered. Where present as "books" or small blocks, it can generally be eliminated in sorting. The amount of block mica is not sufficient to afford any considerable income to the operator.

The albite pegmatite of Pennsylvania occurs in two distinct forms: One of these forms consists of intimately mixed albite and quartz and is similar to the microcline pegmatite except that the content of free quartz as a rule is greater and the feldspar is an opaque white, that of the microcline feldspar being a transparent or translucent white. The results of an analysis of a sample of the albite pegmatite follow.

Analysis of albite pegmatite.

[D. J. Demorest, analyst.]

	Per cent.
Ignition loss	0.42
SiO_2	74.60
Al_2O_3	15.66
Fe_2O_3	.05
TiO_2	.....
CaO	2.75
MgO	.....
Na_2O	6.33
K_2O	.65
	100.46

The high content of quartz in this type of soda pegmatite caused it to be rejected during the early years of feldspar mining in Pennsylvania, but as the pure feldspar masses became exhausted and the graphic granite came into use as a source of feldspar this soda pegmatite came into use also. Hence the feldspar of Pennsylvania that is marketed to-day has not only a higher quartz content, but it also contains more soda than the feldspar mined in the early years of operation in this district. As evidence of this analyses of three samples of potash feldspar taken from the same mill at intervals of three years are given here:

Analyses of samples of potash feldspar taken at 3-year intervals

[D. J. Demorest, analyst.]

Constituent.	Composition of sample.		
	1904	1907	1910
	Per cent.	*Per cent.*	*Per cent.*
Ignition loss	0.80	0.17	0.42
SiO_2	65.78	68.60	69.05
Al_2O_3	19.12	18.40	17.40
Fe_2O_3	....	.54	.15
CaO	.41	.30	.12
MgO	.12	.14	....
Na_2O	1.82	2.00	2.97
K_2O	11.91	10.52	10.03
Total	99.96	100.67	100.14

Another form of albite pegmatite peculiar to Pennsylvania and a small part of the State of Maryland immediately adjacent consists of lenses of practically pure albite coarsely mixed with a magnesium hydrosilicate. Bastin[a] refers to these as pegmatites but not in the sense that they are mixtures of feldspar and quartz, as these deposits contain no free crystalline quartz. The only other minerals intimately associated with the feldspar in these deposits are a dark green hornblende and muscovite. The latter occurs only in small amounts; the hornblende is scattered throughout the deposits and must be carefully removed, because it imparts a dark color to the feldspar when fused. The enormous deposits of this albite in Chester County, for which this district has been justly famous, have been almost exhausted and operations are now confined to a few narrow dikes which are doubtless stringers of the main deposits.

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[a] Bastin, E. S., Economic geology of the feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, 1910, pp. 68-72.

Thus it seems that Pennsylvania has begun to decline as a feldspar producer, and unless new and extensive deposits of superior quality are found, the consumer must look elsewhere for at least a large part of the supply formerly obtained from this State.

MARYLAND.

Maryland's feldspar producing area lies along the line of the Baltimore & Ohio Railroad in Howard and Baltimore Counties. The quality of feldspar obtained from Maryland quarries varies greatly, but this is due both to the methods employed in working the deposits and to the nature of the deposits themselves. In some places the dikes are so weathered that the material is forked over to separate the solid feldspar from the dirt, in a manner similar to that employed in recovering the feldspar from the old quarry dumps in Pennsylvania, but in most places, however, the dike rock is solid. The feldspar is both microcline and albite pegmatite. The microcline pegmatite contains cream and buff feldspar similar in appearance to that of Pennsylvania, but analyses indicate a slightly higher alumina and lower silica content. The quartz content varies greatly for different pegmatites but does not vary excessively throughout any given deposit.

The albite pegmatite of Howard and Baltimore Counties is a chalky white albite or plagioclase mixed with quartz of a faint smoky variety. The feldspar component of this pegmatite does not differ from that of similar deposits in Pennsylvania, but the proportion of albite pegmatite as compared to the microcline variety is much higher in Maryland deposits than in those of Pennsylvania, and hence a more easily fusible pottery feldspar should be obtained from this district than from Pennsylvania.

The greatest obstacle to obtaining high grade feldspar in Maryland is biotite, which occurs in a majority of the dikes in tiny flakes. Its removal is imperative if an acceptable pottery feldspar is to be produced.

Samples of feldspar representing the average of these minerals in Maryland show the following analyses.

Analyses of Maryland pegmatites.

[D. J. Demorest, analyst.]

Constituent.	Microcline pegmatite.		Albite pegmatite.
	A.	B.	C.
	Per cent.	*Per cent.*	*Per cent.*
Ignition loss	0.39	0.13	0.76
SiO_2	65.75	74.20	65.32
Al_2O_3	19.48	14.30	22.00
Fe_2O_3	.20	.20	.21
TiO_2	....	....	....
CaO	....	....	3.78
MgO	....	....	....
Na_2O	1.87	1.59	6.89
K_2O	11.33	9.48	1.06
Total	99.02	99.90	100.02

Small quantities of pure albite pegmatite associated with magnesium hydrosilicate are found in Cecil County along the boundary of Pennsylvania, which are in every way similar to those in Chester County. No deposits of pure albite of commercial size are now open in Maryland and no undeveloped dikes of this class of material are known to exist in that State.

The pegmatite dikes of Maryland have not been operated extensively until very recently, and if care is taken to insure a high-grade product this State can provide much of the feldspar supply which was formerly obtained in Pennsylvania.

VIRGINIA.

Feldspar occurs at numerous points in Virginia, but the actual production has been very small and all the operations have been very short lived. Most of the feldspar found in Virginia has been exposed in mica mines and the methods of mining were not adapted to the economical recovery of the feldspar. Dikes of feldspar have been thus exposed at Jetersville and Amelia Courthouse, Amelia County, and near Hewletts, Hanover County, but the extent of these deposits has never been determined. They all consist of coarse mixtures of microcline and albite of excellent quality with very little associated quartz, although massive sugar quartz is abundant along the walls of the dikes.

In Prince Edward County and in Bedford County a coarse pegmatite is found which should yield a good grade of commercial feldspar. Both of these deposits were worked for a short time only and operations were discontinued although there is no evidence of the deposits being worked out. The dike in Bedford County is exposed over a considerable area and an analysis shows it to be a good mixed feldspar of the following composition:

Analysis of feldspar from dike in Bedford County.

[D. J. Demorest, analyst.]

	Per cent.
Ignition loss	0.10
SiO_2	68.75
Al_2O_3	18.56
Fe_2O_3	.03
CaO	1.25
Na_2O	4.29
K_2O	6.85
Total	99.83

Near Roseland, Nelson County, a broad dike of albite and albite pegmatite carrying a high content of rutile and ilmenite is being worked for rutile. A part of this dike along the north wall contains hornblende and its separation from the feldspar would be difficult, but if carefully mined a great part of the feldspar that does not contain much hornblende could be made marketable after removing the rutile and ilmenite. This feldspar should find a market in the industries and replace in part the shortage of albite.

NORTH CAROLINA.

The feldspar deposits of North Carolina are distributed throughout the mountain section southeast of the Great Smoky Mountains. The most promising districts are those described in Bulletin 53 of the Bureau of Mines[a] as the Cowee district and the Sprucepine district. The former includes parts of Jackson, Macon, and Swain counties and the latter includes parts of Yancey, Mitchell, and Avery counties. The feldspars throughout this State are as a rule cream white microclines with very low soda content. A few small deposits of soda feldspar and anorthoclase were noted but the great majority of deposits in North Carolina are of potash feldspar, most of it being extremely coarse pegmatite, and, as the field is new, a large amount of pure feldspar is to be found as lenses in the pegmatite. Many of the pegmatites are so coarsely crystalline that the quartz content can be almost entirely removed by cobbing. The dikes are seldom large, however, and as most of them stand almost vertical, the problem of mining is more difficult than where the deposits are large lenses or lie nearly flat, as is the case with many deposits farther north. The chief impurities are quartz and muscovite, with smaller amounts of biotite, beryl, and garnets. The latter three minerals, however, are seldom present in quantity sufficient to affect injuriously the color of the product, and the muscovite is generally coarsely crystalline and not generally distributed throughout the entire mass.

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[a] Watts, A. S., Mining and treatment of feldspar and kaolin in the southern Appalachian region: Bull. 53, Bureau of Mines, 1913, p. 12.

The mining in the Cowee district is confined to mining for mica and no attempt is made to remove the feldspar except where it interferes with the mining of the mica. In the Sprucepine district, three feldspar quarries are now in operation and others are to be opened in the near future. The potash feldspars of North Carolina may be safely represented by the following analyses:

Analyses of potash feldspars of North Carolina.

[D. J. Demorest, analyst.]

Constituent.	A.	B.	C.	D.	E.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ignition loss..	0.90	0.17	0.60	0.30	0.40
SiO_2..........	64.48	65.37	63.90	65.68	64.98
Al_2O_3........	19.43	17.92	19.97	19.08	19.45
Fe_2O_3........	.01	.02	.15	.14	....
CaO..........	....	.17	.05	....	.06
MgO..........	....	....	....	....	....
BaO..........	....	....	.70	....	....
K_2O..........	13.19	13.05	13.20	13.09	12.46
Na_2O.........	1.84	2.10	1.01	2.08	2.54
Total.....	99.85	98.80	99.58	100.37	99.83

GEORGIA.

Feldspar-bearing dikes have been found in various parts of Georgia, and the Geological Survey of Georgia has now under way an investigation of these deposits, but as yet no feldspar quarrying has been attempted in the State.

QUALITY OF THE PRODUCT.

The foregoing sets forth the general location and extent of the known feldspar deposits east of the Mississippi River.

In estimating the relative value of a feldspar and its adaptability to the various arts and industries due consideration must be given to the methods employed in the mining, refining, and pulverizing of the crude rock. For example, the feldspars of Maine are not naturally very pure; in fact, no feldspar produced in the United States has so many injurious associate minerals as that of Maine. Nevertheless, the Maine feldspars are furnished to the consumer in a state of purity second to none, except for the quartz content, which can not be eliminated and which must of necessity increase with continued mining in any district. This high state of purity is obtained only by untiring vigilance on the part of the miner and the mill operator to insure the removal of even the smallest particle of iron-bearing impurity and, having freed the crude feldspar of all such impurity, to prevent any contamination during the milling process.

The extra precautions necessary to insure such purity must of necessity increase the cost of the finished product. Not only must extra expense be incurred in handling and storing the crude feldspar before it goes to the mill, but many labor-saving and highly efficient machines must be condemned because of their metal surfaces which come in contact with the sharp edges of the feldspar rock, and being ground off add an almost inappreciable content of iron to the finished product.

Inability to employ many modern machines and appliances has resulted in the general condemnation of the feldspar mining and grinding industry as unwilling to utilize modern appliances, but until machinery can be provided with all wearing faces made of material which will not contaminate the product the operator is to be commended rather than condemned for refusing to employ them.

A point which must be recognized by both the producer and the consumer of ground feldspar is the relation between the quality of the feldspar and the market price. The rejection of any proportion of the rock quarried requires that the accepted rock must be marketed at a price which will cover the expense of the entire quantity quarried unless the rejected material can be disposed of without loss in some other way. As the selection of the more choice parts continues, the amount of material handled continues to increase and this will ultimately result in increasing the cost of the finished product. It is therefore vitally important that every user of feldspar should have a proper understanding of the degree of purity which his business demands and, having done so, seek that grade of material where it can be obtained at the best advantage.

THE COLOR OF FELDSPARS.

The general opinion prevails that the small amounts of impurities which cause a natural feldspar to be cream, buff, brown, or salmon are lost in the fusing process, and that a dark feldspar may fuse to as perfect a white glass as a pure white feldspar. This is not true so far as the results of this investigation have indicated. The intensity of color in the fresh feldspar is, however, no indicator of the intensity of color in the fused feldspar nor of its coloring action in the pottery body or glaze.

In general the feldspars which fuse to the most colorless or white glasses are those which are pure white or colorless. The next in order are the pale salmon and nearly transparent feldspars; then come the cream feldspars, which are generally opaque, or nearly so; the next are the brown and buff feldspars; and the last and most highly colored when fused are the sea-green or olive-green brown feldspars.

This classification is for feldspars which do not contain any foreign material other than that distributed uniformly as a colorant through the entire mass.

The range of tints obtained within the variation of natural feldspars, with the exception of the olive or sea green feldspars, are only possible of detection where the materials are prepared with the utmost care. Any dirt or dust on the surfaces of the crude feldspar or carelessness in the crushing or grinding process may result in a fused product of a color far inferior to any obtainable by fusing the darkest colored natural feldspar, the olive-green or sea-green feldspars excepted.

The problem, then, resolves itself into one not entirely of obtaining the feldspar of the best natural color, but more especially of guarding against the introduction of impurities naturally associated with the feldspars and also of impurities which may be introduced in the milling.

Plates II and III show the range of color in the natural feldspars.

DESCRIPTION OF SPECIMENS SHOWN IN PLATES II AND III.

In the following list are described the specimens shown in Plates II and III. All of the feldspars shown in Plates II and III, except H and L (Pl. III), fuse to white or colorless glass.

A. Microcline from Carolina Mineral Co. quarry, at Penland, Mitchell County, N. C. For a description of this deposit see location 110, Bureau of Mines Bulletin 53, page 100.

B. Microcline from Johnson mica mine, near Plumtree, Avery County, N. C. For a description of this deposit see location 106, Bureau of Mines Bulletin 53, page 112.

C. Microcline from Barrett quarry, Essex County, N. Y. For a description of this deposit see location 59, page 133.

D. Green microcline from Rutherford mica mine, Amelia County, Va. For a description of this deposit see location 110, page 167.

E. Albite from Sylmar quarry, Chester County, Pa. For a description of this deposit see location 89, page 156.

F. Microcline from Rhodes quarry, northeast of Northville, Fulton County, N. Y. For a description of this deposit see location 64, page 139.

G. Microcline from Kinkel quarry, near Bedford, Westchester County, N. Y. For a description of this deposit see location 68, page 142.

H. Greenish brown microcline from Berry quarry, Auburn, Androscoggin County, Me. For a description of this deposit see location 40, page 122.

I. Transparent albite from Saunders, near Hewletts, Hanover County, Va. For a description of this deposit see location 114, page 169.

J. Microcline from old Perry quarry, Phippsburg Peninsula, Sagadahoc County, Me. For a description of this deposit see location 21, page 110.

K. Microcline from old Claspka quarry near Batchellerville, Saratoga County, N. Y. For a description of this deposit see location 63, page 137.

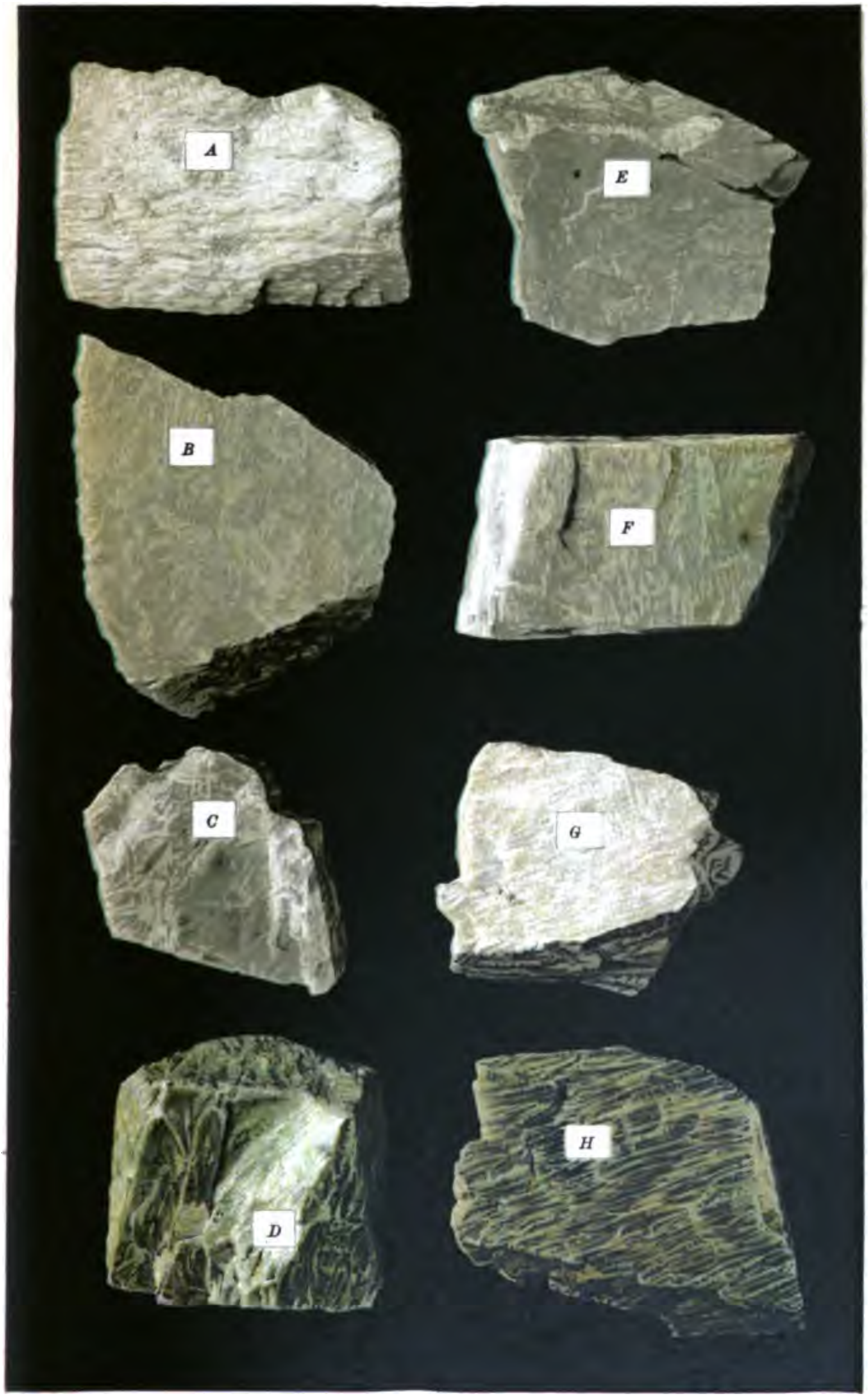
L. Andesine from Crown Point quarry, Essex County, N. Y. For a description of this deposit see location 58, page 132.

M. Microcline from Eureka quarry, Portland, Middlesex County, Conn. For a description of this deposit see location 50, page 127.

N. Microcline from Claspka quarry near Batchellerville, Saratoga County, N. Y. For a description of this deposit see location 62, page 136.

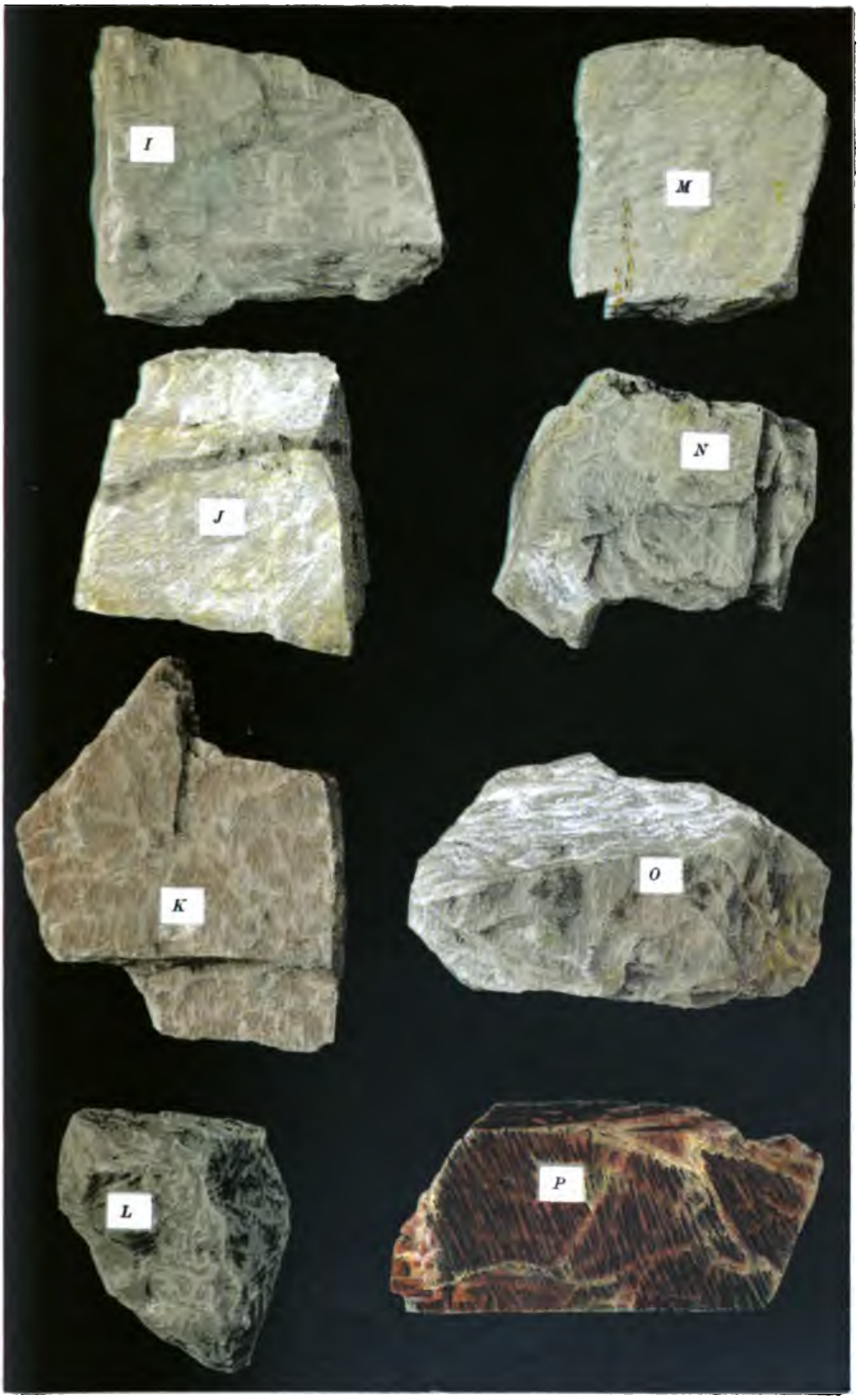
O. Microcline from Tyrol Mountain quarry southwest of Northville, Fulton County, N. Y. For a description of this deposit see location 66, page 140.

P. Microcline from Richardson quarry, Godfrey, Ontario, Canada.



[illegible]

MICROCLINE AND ALBITE IN NATURAL COLORS.
FOR DESCRIPTION SEE ACCOMPANYING TEXT.



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ANDESINE, MICROCLINE, AND ALBITE IN NATURAL COLORS.
FOR DESCRIPTION SEE ACCOMPANYING TEXT.

MINERALS ASSOCIATED WITH FELDSPAR IN PEGMATITE.

A knowledge of the minerals associated with feldspar in pegmatite is essential if a proper estimation of the value of the dike material is to be arrived at.

The chief minerals associated with the feldspar in pegmatite are quartz, muscovite (white mica), biotite (black mica), garnets, beryl, tourmaline, magnetite.

Although pegmatites are essentially coarsely crystalline mixtures of feldspars and quartz, the associated minerals other than quartz are important as their amount and the mode of their occurrence have a vital influence on the industrial value of the pegmatite.

QUARTZ.

Quartz is an essential mineral of pegmatite and may be either mixed with the feldspar or intercrystallized with it as graphic granite; most pegmatite dikes also contain intruded lenses or bands of quartz that differ in texture and appearance from ordinary pegmatite quartz. This quartz has a granular structure in most deposits and is commonly known as sugar quartz. It is white or pink in color and is opaque or semiopaque, owing to fracture planes and to minute bubbles of gases, principally water vapor, that have been entrapped in the solidifying silica. In the smoky quartz of pegmatite these bubbles also contain organic material, and this causes the dark smoky color.

These masses of quartz are oftenest found along the walls of the dike, where the shrinkage of dike material in solidifying formed cracks in which this silica was deposited. The occurrence of lenses of sugar quartz completely separated from the walls and often in the very center of the dike are doubtless due to temporary crevices in the lower parts of the pegmatite mass. In a vast majority of cases, the masses of sugar quartz included within the pegmatite are found to communicate by stringers with quartz bands along the walls.

MUSCOVITE.

Muscovite (white mica) is a constituent of nearly every pegmatite. Crystals of this mineral occur in all sizes from 3 feet in diameter to tiny flakes which require a microscope to identify them. Muscovite in large crystals or in aggregates known as "books" is generally found between bands near the walls or imbedded in a comparatively narrow band of highly mineralized material adjoining the walling quartz. The continuation of muscovite in quantity between any given bands of a dike is uncertain; a rich muscovite bearing band may suddenly pinch out or disappear along one wall of a dike and reappear between two bands near the center of the dike, or may even be transferred to the band adjoining the quartz or the wall band on the opposite side of the dike. Where the dike rock is not in distinct bands or the pegmatite is only moderately coarse the muscovite is often present in fine flakes, which are distributed throughout the entire mass. In the latter case its separation from the feldspar is difficult and often impossible except at a great sacrifice of feldspar.

BIOTITE.

Biotite (black mica) is an associate mineral of nearly all pegmatite, but its mode of occurrence is not similar to that of muscovite. Biotite is generally present as a chief constituent or is practically absent. Its commonest form is in lathlike crystals, which often are 3 feet in length and 4 to 6 inches in diameter, but the thickness rarely exceeds one-fourth of an inch. Such crystals are in many places matted together with smaller crystals in a pegmatite, rendering that part of the deposit too impure to justify sorting by hand. Fortunately, such masses are often associated with masses practically free from biotite; hence its presence in coarse crystals need not condemn the entire deposit. Where biotite occurs as crystals less than 1 inch in maximum dimension it is generally distributed throughout the mass and its complete separation is impracticable. Owing to the brittleness of biotite it breaks and becomes a powder under treatment which would not shatter the more elastic muscovite and hence is even more difficult to remove than muscovite. Such pegmatite can be utilized in the industries where a white-burning feldspar is not required.

GARNET.

Garnet is a common constituent of pegmatite and is one of the most annoying minerals with which the feldspar producer has to deal. The garnet crystals are often so tiny as to escape any but the closest scrutiny. Only in rare cases are they of sufficient size to permit of removal by cobbing, and as even a few coarse crystals indicate the presence of many smaller ones, the finding of garnets in a pegmatite is with many operators sufficient cause for doubting its quality.

The process of sorting material from a dike containing scattered garnet-bearing masses is laborious and expensive and too often unprofitable. The rock must be broken to small size and all of it carefully sorted by hand.

In dikes of a pronounced banded structure the garnets are often confined to one or two bands, and where such is the case they can be eliminated by rejecting these bands.

Garnet generally occurs as andradite (calcium iron silicate) of the approximate composition $3CaO.Fe_2O_3.3SiO_2$, and its coloring power in feldspar is very great. An addition of 1 per cent of garnet to feldspar that fuses to milky white causes it to fuse to an intense yellow brown, and the presence of one-tenth of 1 per cent of garnet would render a feldspar unmarketable as a pottery feldspar. Garnet grinds at about the same rate as feldspar, and its presence in a feldspar imparts a faint flesh tint to the powdered rock. As many feldspars are naturally flesh colored, the presence of garnet can not be detected by this color and generally is not suspected until it is shown by the mass fusing to a yellow color in finely pulverized feldspars or by brown specks in coarsely ground feldspar.

BERYL.

Beryl occurs chiefly in pegmatite rich in feldspar, and the beryl crystals, which are hexagonal, are generally imbedded in masses of pure feldspar.

Although beryl may be golden, blue, green, or even pink, the vast majority of the beryl crystals in pegmatite are pale blue with a vitreous luster. The wide variety of tints in feldspar and its similar luster makes it very difficult to distinguish beryl from feldspar, except where a face of the beryl crystal is exposed. Beryl is notably harder than feldspar and generally has a conchoidal fracture, but as most massive feldspar breaks irregularly, the faces exposed resemble conchoidal fractures in many instances. If the crude material was not reduced by too powerful a crusher, the beryl, being harder, could doubtless be largely removed, but to eliminate it from pulverized rock would be impossible. The only practical means of separating beryl from crude feldspar is to carefully scrutinize the rock in the quarry, and wherever beryl is detected to watch for it after each blast and sort the beryl-bearing rock from the marketable feldspar.

Beryl has the composition $3BeO.Al_2O_3.6SiO_2$. It does not discolor the fused feldspar but makes it opaque and in small amounts it lowers the deformation temperature of the feldspar. Its chief disadvantage is its tendency to reduce the translucency of the ware.

TOURMALINE.

Tourmaline usually occurs in pegmatite rich in feldspar and containing very little biotite. It is commonly black, although pink, green, blue, and colorless crystals are occasionally found, and furnish gems when transparent. Tourmaline as a rule is in the form of irregular rods, 3 to 15 inches long and one-half inch to 3 inches in diameter, imbedded in the feldspar. Being black, it is easily detected and its complete removal is imperative if the feldspar is to be marketed for pottery uses.

Tourmaline has a very complex and variable composition of approximately $3R_2O.SiO_2$, in which R may represent a mixture of aluminum, boron, magnesium, and iron compounds and alkalies or any of them.

MAGNETITE.

Magnetite or black oxide of iron is sometimes found in pegmatite. Its presence absolutely condemns the feldspar for ceramic uses because the particles of magnetite are usually almost microscopically small so that the sorting of such material is extremely expensive. Attempts to remove the magnetite by means of electromagnets have failed because of the difficulty of separating the feldspar and magnetite by any system of rolls or crushers.

Magnetite has the composition Fe_3O_4 and its presence in the pulverized feldspar is evidenced by minute black specks. In the fused feldspar the magnetite shows as black specks surrounded by yellowish or brownish zones of ferric silicate.

GENERAL COMPOSITION OF THE MARKETED PRODUCT.

In general a pegmatite must have a comparatively high feldspar content if its quarrying for feldspar is to be profitable under ordinary conditions.

The average pegmatites being marketed as feldspar contain about 80 per cent of feldspar. The other 20 per cent is principally quartz, as the presence in appreciable quantity of any mineral which might discolor the ware would result in the condemnation of the entire output of a quarry.

FELDSPAR CLASSIFICATION.

Feldspars may be classified according to their alkali constituent into four distinct groups:

Potash feldspars, known as microcline or orthoclase, $KAlSi_3O_8$.

Soda feldspar, known as albite, $NaAlSi_3O_8$.

Lime feldspar, known as anorthite, $CaAl_2Si_2O_8$.

Barium feldspar, known as celsian, $BaAl_2Si_2O_8$.

In nature these minerals are rarely found in the pure state, but commonly occur as intimately crystalized masses of two or more different feldspars. Some of the feldspars apparently combine and form homogeneous crystals of definite composition, whereas others are isomorphous mixtures.

Iddings[a] reports the following varieties as having been recognized:

Soda-orthoclase $(KNa)AlSi_3O_8$.

Anorthoclase or soda-microcline, $NaKAlSi_3O_8$.

Plagioclase or lime-soda feldspar series $\left\{\begin{array}{l} n(NaAlSi_3O_8). \\ m(CaAl_2Si_2O_8). \end{array}\right.$

Hyalophane or barium-potash feldspar $\left\{\begin{array}{l} n(KAlSi_3O_8). \\ m(BaAl_2Si_2O_8). \end{array}\right.$

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[a] Iddings, J. P., Rock minerals, 1911, p. 205.

In the plagioclase series the ratio of soda feldspar to lime feldspar may vary from $\frac{\text{6 molecules soda feldspar}}{\text{1 molecule lime feldspar}}$ to $\frac{\text{1 molecule soda feldspar}}{\text{6 molecules lime feldspar}}$. Soda-lime feldspars containing less than 1:6 ratio are classified with the pure feldspar which they approach.

The hyalophane series, as classified by Rosenbusch,[a] comprises such barium-potash feldspars as contain between 7.5 and 16.4 per cent BaO. Those potash feldspars which contain less than 7.5 per cent BaO are called orthoclase and those which contain more than 16.4 per cent BaO are classed as celsian.

POTASH FELDSPARS.

Potash feldspar is found in nature in two forms—namely, microcline, which is the chief constituent of the ordinary feldspar of commerce, and orthoclase, which is less frequently met with, although until recently the microcline of commerce has gone by this name. The error has, however, been of no industrial importance because the two minerals are identically the same in chemical composition, differing only in crystalline form and in optical properties.

Microcline has the molecular formula $K_2OAl_2O_36SiO_2$ and is approximately of the composition K_2O, 16.9 per cent; Al_2O_3, 18.4 per cent; and SiO_2, 64.7 per cent; its specific gravity is 2.54; it has a hardness of 6 to 6.5; and belongs to the triclinic system. Its color is generally white, grayish yellow, yellow, or any shade of red from light rose to brick color, the red color being due to finely divided iron oxide or hydroxide. It may be green (amazon stone) in transmitted light. In thin sections it is colorless. The Na_2O content varies up to 4 per cent and that of the CaO seldom exceeds 05 per cent.

As the microclines which are richest in Na_2O and CaO are also mechanically mixed with the largest amounts of albite and oligoclase-albite, it is not improbable that Na_2O and CaO do not belong to the true microcline molecule. As the Na_2O content increases in a microcline the specific gravity increases and with a soda content of 4 per cent may be as much as 2.57.

Orthoclase varies in few respects from microcline. It crystallizes in the monoclinic system, but the polysynthetic twinning that is characteristic of microcline may be submicroscopic in orthoclase and hence not apparent. It has the same specific gravity and color as microcline, and has a hardness of 6.

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[a] Rosenbusch, K. H. F., Mikrokopische Physiographie der Mineralien und Gesteine, Bd. 1, Heft 2, 1908, p. 309–313.

SODA FELDSPARS.

Soda feldspar is found in nature in two forms—namely, albite, which is the form ordinarily encountered, and cleavelandite, which is a lamellar variety of albite, differing from it only in massive structure and having the same optical and physical properties.

The molecular formula of albite is $Na_2O.Al_2O_3.6SiO_2$. Its approximate composition is as follows: Na_2O, 11.8 per cent; Al_2O_3, 19.4 per cent; SiO_2, 68.8 per cent. Albite has a specific gravity of 2.624, ranges in hardness from 6 to 6.5, and crystallizes in the triclinic form. Its color is generally white, although it may be reddish, greenish, bluish, or gray. Cleavelandite often displays a bluish tint. In thin sections albite is colorless.

The Na_2O in albite may be replaced by CaO in amounts less than 3 per cent CaO and the mineral still retain its name. When the CaO content exceeds 3 per cent, however, it is classified as a lime-soda feldspar, of which there are now recognized a series of five numbers between pure albite and pure anorthite. These form the plagioclase subgroup.

LIME FELDSPAR.

Lime feldspar is known as anorthite and in its pure state occurs only in one form. This feldspar has the molecular formula $CaO.Al_2O_3.2SiO_2$, and contains the following percentages of these compounds: CaO, 20.1; Al_2O_3, 36.62; and SiO_2, 43.28 per cent. The mineral has a specific gravity of 2.758, a hardness of 6 to 6.5, and belongs to the triclinic system. It is white, grayish, or reddish, but is colorless in thin sections.

The CaO in anorthite may be replaced by Na_2O in amounts less than 1.6 per cent. When the Na_2O content exceeds 1.6 per cent the feldspar becomes one of the plagioclase subgroup.

BARIUM FELDSPAR.

Barium feldspar is known as celsian and in the pure state occurs only in one form. The molecular formula of celsian is $BaO.Al_2O_3.2SiO_2$. The mineral contains 41.8 per cent BaO, 27.2 per cent Al_2O_3, and 32 per cent SiO_2, and has a specific gravity of 3.38, a hardness of 6 to 6.5; crystallizes in monoclinic form, and is colorless unless stained by impurities.

FELDSPAR SERIES.

Aside from these four principal feldspars, there are many feldspars which are made up of two fluxes.

Anorthoclase or soda-microcline is a feldspar in which more than one-half the potash is replaced by soda.

Hyalophane is a feldspar in which part of the potash is replaced by barium.

Plagioclases are lime-soda feldspars which are a group of feldspars whose members form a continuous series connecting albite and anorthite, as may be seen from the following table:

Feldspars, their formulas and limits of composition.[a]

Name.	Formula limits.	Limits of composition.					
		BaO.	K_2O.	Na_2O.	CaO.	Al_2O_3.	SiO_2.
Calsian	$BaAl_2Si_2O_8$	40.8				27.2	32.0
	$(BaAl_2Si_2O_8)\ 2\ (KAlSi_3O_8)$	16.5	10.1			21.9	51.5
Hyalophane	$(BaAl_2Si_2O_8)\ 2\ (KAlSi_3O_8)$	16.5	10.1			21.9	51.5
	$(BaAl_2Si_2O_8)\ 6\ (KAlSi_3O_8)$	7.5	13.8			20.0	58.7
Microcline or orthoclase.	$KAlSi_3O_8$		16.9			18.4	64.7
Anorthoclase	$(2KAlSi_3O_8)\ 3\ (NaAlSi_3O_8)$		7.0	6.9		19.0	67.1
	$(KAlSi_3O_8)\ 6\ (NaAlSi_3O_8)$		2.5	10.1		19.3	68.1
Albite	$NaAlSi_3O_8$			11.8		19.4	68.8
Oligoclase	$6(NaAlSi_3O_8)\ (CaAl_2Si_2O_8)$			10.0	3.0	22.1	64.9
	$2(NaAlSi_3O_8)\ (CaAl_2Si_2O_8)$			7.7	7.0	25.4	59.9
Andesine	$3(NaAlSi_3O_8)\ 2\ (CaAl_2Si_2O_8)$			6.9	8.3	26.5	58.3
	$4(NaAlSi_3O_8)\ 3\ (CaAl_2Si_2O_8)$			6.6	8.9	27.0	57.5
Labradorite	$(NaAlSi_3O_8)\ (CaAl_2Si_2O_8)$			5.7	10.3	28.3	55.7
	$(NaAlSi_3O_8)\ 2\ (CaAl_2Si_2O_8)$			3.8	13.7	31.1	51.4
Bytownite	$(NaAlSi_3O_8)\ 3\ (CaAl_2Si_2O_8)$			2.8	15.8	32.5	49.4
	$(NaAlSi_3O_8)\ 6\ (CaAl_2Si_2O_8)$			1.5	17.4	34.3	46.8
Anorthite	$CaAl_2Si_2O_8$				20.1	36.6	43.3

[a] Formulas are according to Rosenbusch, Mikrokopische Physiographie der Mineralien and Gesteine. Authorities do not agree as to the exact formula limits, but the differences are negligible in most cases.

The above formulas represent only the pure minerals and combinations of two pure minerals. In nature one rarely finds a pure feldspar—that is, one containing but one alkali—in large quantity, and feldspars consisting of mixtures of but two pure minerals are comparatively rare. The manufacturer therefore has little use for data based on the pure minerals except as it conduces to a better understanding of the complex feldspars with which he has to deal.

The feldspars most extensively used in the industries are the two forms of potash-feldspars, microcline and orthoclase. The chemical compositions and physical properties of these two minerals are identical, and for all practical purposes they may be dealt with as one mineral, microcline, which is the form generally encountered.

In commerce the term "potash feldspar" is used in referring to any feldspar in which potassium is the prevailing flux, and even though the proportion of potassium is so low as to make the chemical composition approach hyalophane or anorthoclase, the latter names have never been employed in the industries.

As indicated in the above list, no series of feldspars occurs in nature in which the potash is replaced by lime, and if a potash feldspar contains any appreciable amount of CaO it is safe to assume that it contains an equal or greater amount of Na_2O, the two elements being introduced in one of the plagioclases, which is perthitically intergrown in the microcline.

Hyalophane is rarely encountered in commercial quantity. Barium as a constituent of feldspars is not uncommon but rarely exceeds 0.5 per cent and generally, if present, the proportion is less than 0.25 per cent. A study of the action of barium in feldspars has not been attempted in connection with this investigation, because the feldspars of the district contain little or no barium. However, it is a matter of record that potash feldspars which contain even a small amount of barium display a marked decrease in viscosity when fused, as compared with similar feldspars which contain no barium.

Mixtures of microcline and albite or mixtures of microcline and albite-rich members of the plagioclase series are really the feldspars with which the manufacturer who uses the material popularly known as "potash feldspar" has to deal.

In purchasing "soda feldspar" the manufacturer never obtains pure albite because deposits of pure albite of commercial size do not exist. The nearest approach to pure albite which is obtainable in commercial quantity is a feldspar high in soda content and relatively low in potash and lime content.

The impression prevails among users of feldspar that "soda feldspar" or albite is the softest member and "potash feldspars" or microcline is the hardest member of a feldspar series, and that the hardness of any mixture of these two will be proportionate to its relative content of the two extremes; that is, the deformation-temperature curve of potash feldspar-soda feldspar mixtures is supposed to be a straight vertical line with soda feldspar as the lowest point and potash feldspar as the highest point.

The results of a study by the writer of a large number of feldspars containing both potash and soda as fluxes indicates that this assumption is not true, but in making feldspar analyses there are so many slight variables which may affect the result that the exact cause of variation in any particular property is extremely difficult to determine. However, it was noted that feldspars with a moderately high content of soda and a proportionately low content of potash showed a marked tendency to deform at lower temperatures than did the relatively pure soda feldspars, as is shown by the following analyses of feldspars, arranged in the order of their deformation:

Feldspars classified in the order in which they deform.

Constituent.	Order of deformation and composition.		
	No. 1.	No. 2.	No. 3.
	Per cent.	*Per cent.*	*Per cent.*
H_2O.......	0.30	0.10	0.20
SiO_2.......	65.40	68.75	68.18
Al_2O_3......	20.70	18.56	20.12
Fe_2O_3......	.10	.03	.05
CaO.......	1.60	1.25	.85
MgO......	Trace.	Trace.	.05
K_2O.......	6.00	6.85	.66
Na_2O......	6.10	4.29	9.38
Total..	100.20	99.83	99.49

The ordinary conception would lead to the assumption that No. 3 is the most easily fusible of the three instead of being the least fusible, as it really is.

EFFECT OF COMPOSITION ON PROPERTIES OF FELDSPAR.

DEFORMATION TESTS OF POTASH FELDSPAR-SODA FELDSPAR MIXTURES.

In order to determine the most fusible mixture of potash and soda feldspars, a series of mixtures of these two feldspars was prepared and deformation studies made.

The feldspars used in preparing the series of mixtures had the following composition:

Composition of feldspars employed.

	H_2O.	SiO.	Al_2O_3.	Fe_2O_3.	TiO_2.	CaO.	MgO.	K_2O.	Na_2O.	BaO.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Potash feldspar......	0.50	64.3	19.64	0.08	Trace.	Trace.	Trace.	14.00	1.32	0.17
Soda feldspar.........	.20	68.18	20.12	.05	...do..	0.85	0.05	.66	9.38	....

Neither of the above feldspars is a pure type, each of them being a mixed feldspar that was high in the particular feldspar sought.

Unfortunately, in all the large feldspar deposits the feldspar contains less than the theoretical amount of alkali, although as a rule the ratio of Al_2O_3 to SiO_2 closely approaches the theoretical if the free quartz in the pegmatite is removed. This shortage of alkali is doubtless due to slight alteration of the feldspar, but no information is available pointing to the formation of products other than kaolin by the weathering of feldspar.

To subdivide an ordinary feldspar into its possible mineral components by a process of calculation based upon its alkali content results in confusion, as an excess of Al_2O_3 and SiO_2 remains after all possible minerals have been deducted. The absence of sufficient combined water makes it impossible to calculate the excess Al_2O_3 into kaolin, although the Al_2O_3 must be in other than the free state because none dissolves in hydrochloric acid.

As the feldspars used in this investigation must be divided into microcline and albite content, the ratio of K_2O to Na_2O has been chosen as the basis of division after that amount has been deducted which can be calculated as kaolin, the combined water being used as the basis of this latter calculation.

The result of this subdivision is as follows:

Composition of feldspars on basis of microcline, albite, and kaolin content.

	Microcline.	Albite.	Kaolin.
	Per cent.	*Per cent.*	*Per cent.*
Potash feldspar..	85.0	11.5	3.5
Soda feldspar....	4.5	94.0	1.5

The mixtures of these two feldspars as used in the investigation are as follows:

Mixtures of feldspars used.

Proportions in mixture.		Approximate normal constitution.	
		Albite.	Microcline.
	Per cent.	*Per cent.*	*Per cent.*
Soda feldspar.....	100	94	4.5
Soda feldspar.....	90	16	12.5
Potash feldspar...	10		
Soda feldspar.....	80	77.5	21.0
Potash feldspar...	20		
Soda feldspar.....	70	69.0	29.0
Potash feldspar...	30		
Soda feldspar.....	60	61.0	37.0
Potash feldspar...	40		
Soda feldspar.....	50	53.0	45.0
Potash feldspar...	50		
Soda feldspar.....	40	44.5	53.0
Potash feldspar...	60		
Soda feldspar.....	30	36.0	61.0
Potash feldspar...	70		
Soda feldspar.....	20	28.0	69.0
Potash feldspar...	80		
Soda feldspar.....	10	20.0	77.0
Potash feldspar...	90		
Potash feldspar...	100	11.5	85.0

RESULTS OF TESTS.

The order and rate of deformation of these potash feldspar-soda feldspar mixtures, as compared with similar properties of standard pyrometric cones Nos. 6, 7, 8, 9, and 10, are shown in figure 1. The percentage composition of the feldspar mixtures are shown at the top of the diagram, and the time interval and temperature increase as indicated by deformation of the standard cones are shown at the left.

DISCUSSION OF RESULTS.

The data in figure 1 are remarkably sharply defined as regards the end numbers of this series, but unfortunately the deformation ranges of the three softest members are so nearly the same that a number of checks must be made before the eutectic can be established.

From this preliminary test it seems that a mixture of approximately 69 per cent albite and 29 per cent microcline begins to deform at a lower temperature and completes the deformation process earlier than any other member of the series tested. The time required for the deformation of a cone made from this mixture was only half that required for a similar deformation of standard cone 6, the cone starting to deform at approximately the same time as cone 6 and being completely deformed when cone 6 had only half deformed.

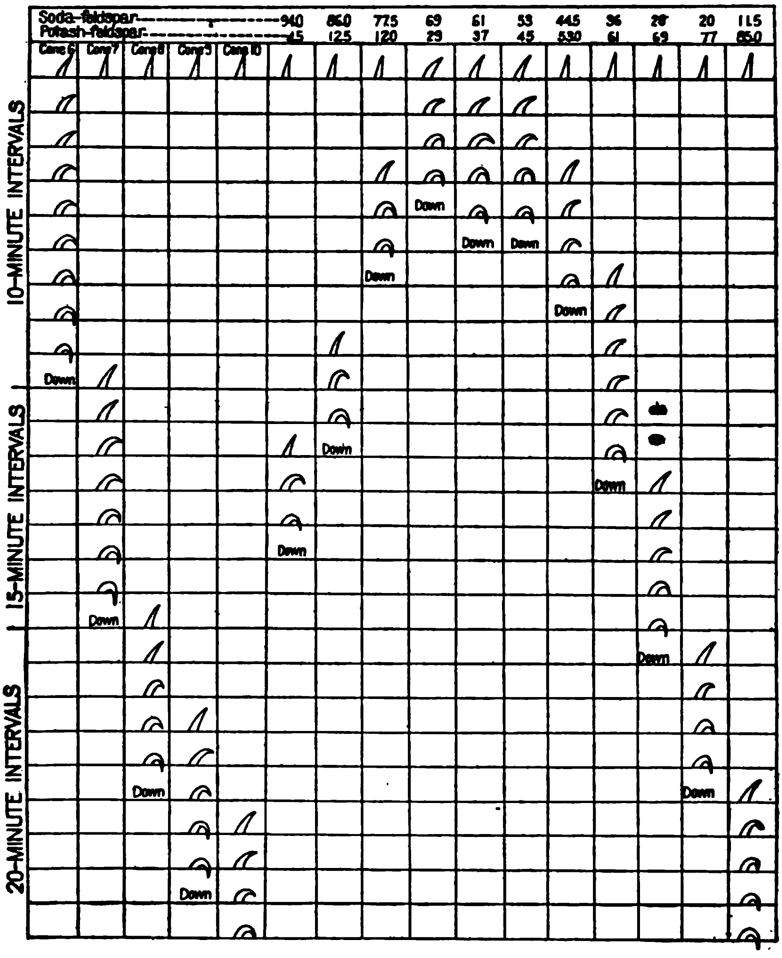

FIGURE 1.—Deformation of potash feldspar-soda feldspar cones.

Mixtures ranging from one that was 77.5 per cent albite and 21 per cent microcline to one that was 44.5 per cent albite and 53 per cent microcline completely deformed before cone 6 had completed deformation.

The albite used in this study deformed at about the same rate as the eutectic mixture, but proved to be nearly one cone harder. The rate of deformation of the mixtures containing a higher percentage of microcline than the eutectic mixture decreases as the microcline content increases, the potash-feldspar end of the series having a time range of deformation equal to twice that of the albite.

Thus it is shown that a high soda content does not indicate a low deformation temperature. Also the approximate proportion of soda feldspar can not be determined except by a careful observation of the rate of deformation.

DEFORMATION TESTS OF FELDSPAR-QUARTZ MIXTURES.

One of the most confusing questions which confronts the user of feldspar is the extent to which the addition of quartz or free silica affects the pyrometric behavior of feldspar. In nature quartz is almost invariably associated with feldspar, and in most cases a complete separation of the two minerals would be very expensive if not impossible. Any feldspar purchased in the pulverized state is, therefore, very likely to contain a certain amount of free quartz unless special arrangement was made to have all quartz removed from the crude feldspar.

In order that a clearer understanding may be had of the effect of quartz on the different feldspars as regards deformation behavior, a study was made of potash feldspar-quartz mixtures and of soda feldspar-quartz mixtures.

The feldspars used were the same as those used in the potash feldspar-soda feldspar mixtures. These, as heretofore explained, are not pure minerals, but are as nearly pure as are obtainable in commercial quantities.

EXPERIMENTS WITH POTASH FELDSPAR-QUARTZ MIXTURES.

The composition of the potash feldspar and the quartz used was as follows:

Composition of potash feldspar and of quartz used.

[D. J. Demorest, analyst.]

Potash feldspar.		Quartz.	
	Per cent.		*Per cent.*
H_2O	0.50	Loss on ignition	0.11
SiO_2	64.30	SiO_2	99.18
Al_2O_3	19.64	Al_2O_3	.00
Fe_2O_3	0.08	Fe_2O_3	.26
TiO_2	Trace.	TiO_2	.01
CaO	Trace.	CaO	.01
MgO	Trace.	MgO	.01
BaO	.17		
K_2O	14.00		
Na_2O	1.32		
	100.01		99.58

The materials were ground to pass a 200-mesh screen and mixed in the proper proportions dry; the mixture was then made plastic by a small addition of dextrine solution. The various mixtures were molded into cones similar in shape and size to the standard pyrometric cones of commerce. The results of the tests are shown in figure 2. The proportions of feldspar and quartz in the various mixtures are recorded across the top of the diagram, and the intervals of time and of temperature as indicated by the deformation of the standard cones are shown along the left margin.

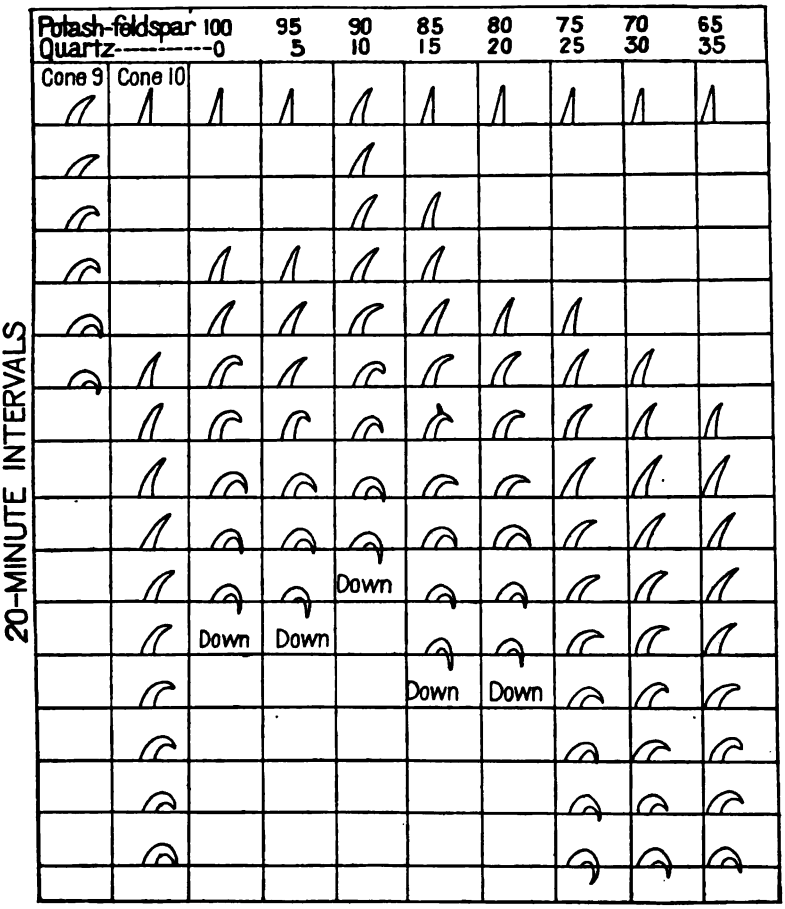
Potash-feldspar 100 95 90 85 80 75 70 65
Quartz ---------- 0 5 10 15 20 25 30 35
Cone 9
Cone 10
20-MINUTE INTERVALS
Down
Down
Down
Down
Down

FIGURE 2.—Deformation of potash feldspar-quartz cones.

According to the results given in figure 2 the mixture of 90 per cent potash feldspar and 10 per cent quartz began to deform and completed deformation before any other mixture, and is therefore the deformation eutectic of this feldspar and quartz. The intervals between the deformation of this mixture and those of the mixtures containing about 5 per cent of quartz are so small that in practice the difference would hardly be noted unless carefully watched for. The pure feldspar deformed at the same temperature and rate as the mixture consisting of 95 per cent feldspar and 5 per cent quartz, and only when a mixture of 80 per cent feldspar and 20 per cent quartz was reached did any noticeable difference appear in the behavior of the cones. This mixture is slightly more refractory than the pure feldspar. The mixture consisting of 65 per cent feldspar and 35 per cent quartz is hardly more than one-half cone harder than the pure feldspar

CONCLUSIONS.

Feldspar high in potash and very low in soda content is only slightly affected by additions of quartz or flint. Substitution of quartz for feldspar in proportions up to 20 per cent may be made without materially affecting the temperature at which deformation begins or is completed. Substitution of quartz for feldspar up to 35 per cent may be made without affecting the deformation temperature more than one-half cone.

The foregoing indicates the futility of attempting to ascertain the extent to which a feldspar is adulterated with quartz by the deformation test alone.

DEFORMATION TESTS OF SODA FELDSPAR-QUARTZ MIXTURES.

A series of tests was also made with mixtures of soda feldspar and quartz. The soda feldspar and quartz used in the tests had the following composition:

Composition of soda feldspar and quartz used in tests.

[D. J. Demorest, analyst.]

Soda feldspar.		Quartz.	
	Per cent.		*Per cent.*
H_2O	0.20	Loss on ignition	0.11
SiO_2	68.18	SiO_2	99.18
Al_2O_3	20.12	Al_2O_3	.00
Fe_2O_3	.05	Fe_2O_3	.26
TiO_2	Trace.	TiO_2	.01
CaO	.85	CaO	.01
MgO	.05	MgO	.01
K_2O	.66		
Na_2O	9.38		
	99.49		99.58

These materials were ground to pass a 200-mesh sieve and mixed in the proper proportions in the dry state. A small amount of dextrine solution was then added to each mixture and they were molded into cones similar in size and shape to the standard pyrometric cones of commerce against which they were to be tested. The results of the test are shown in figure 3.

The percentages of soda feldspar and quartz in the various mixtures are recorded across the top of the diagram, and the time and the temperature intervals as indicated by the deformation of standard cones are shown on the left margin.

DISCUSSION OF RESULTS OF TESTS.

The above data indicates that additions of quartz do not affect soda feldspar in a manner similar to potash feldspar. None of the mixtures of soda feldspar and quartz, up to one containing 30 per cent of quartz, began to deform or completed deformation at a lower temperature than the pure soda feldspar. The mixture of 75 soda feldspar and 25 quartz, however, deformed more quickly after its deformation temperature was reached than did the pure soda feldspar. The rate of deformation, as indicated by the time intervals, is more rapid with soda feldspar and with all mixtures of soda feldspar and quartz than with potash feldspar or any mixture of potash feldspar and quartz. A rapid rate of deformation in soda feldspar-quartz mixtures may be a highly desirable feature in mixtures used for certain glazes, where fluidity is often desired, but in porcelain bodies it would be a detriment because the shorter the deformation range the greater would be the danger of warping.

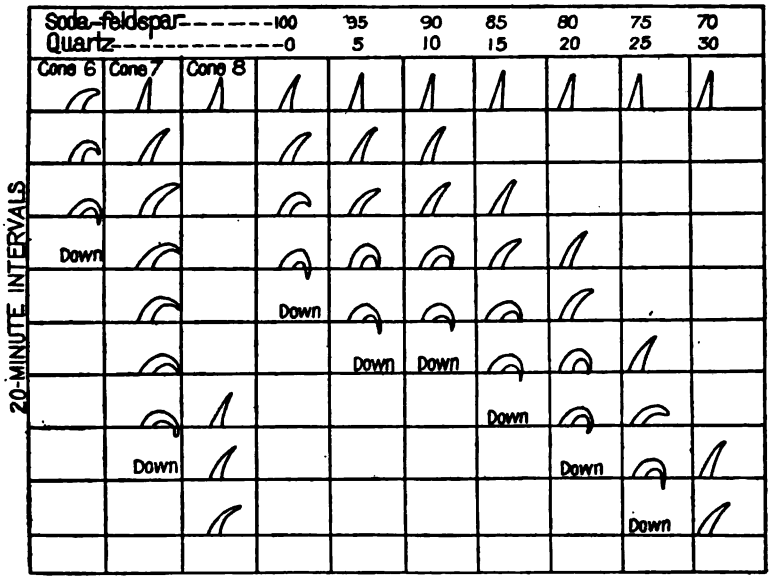
Soda-feldspar------100 95 90 85 80 75 70
Quartz----------0 5 10 15 20 25 30
Cone 6
Cone 7
Cone 8
20-MINUTE INTERVALS
Down
Down
Down
Down
Down
Down
Down
Down

FIGURE 3.—Deformation of soda feldspar-quartz cones.

DEFORMATION TESTS OF COMMERCIAL POTASH FELDSPAR-QUARTZ MIXTURES.

Another series of tests with mixtures of quartz and a feldspar which falls between the potash feldspar and the soda feldspar used in the investigations previously described, is of interest here as indicating the possible direction of the deformation curve of eutectic mixtures that lie between these two extremes. This feldspar contains 50 per cent more soda feldspar than the potash feldspar just described and is a good average of the feldspar offered for sale as potash feldspar. For convenience it is here referred to as commercial potash feldspar.

The analysis of this feldspar is given below. The quartz used was of the same composition as that used in the previous tests.

Composition of commercial potash feldspar.

	Per cent.
H_2O	0.17
SiO_2	65.37
Al_2O_3	17.92
Fe_2O_3	.02
TiO_2	Trace
CaO	.17
MgO	Trace
BaO	.15
K_2O	13.05
Na_2O	2.10
	98.95

The materials were ground and the mixtures prepared in the same manner as in the previous tests. The standard cones against which this series was tested included standard pyrometric cones 8 and 9, whereas the soda feldspar-quartz series was within the range of standard cones 6, 7, and 8, and the potash feldspar-quartz series was within the range of standard cones 9 and 10. Therefore this feldspar falls between the other two although a careful study of the results obtained reveals the fact that it more nearly approaches in behavior the regular potash feldspar than the soda feldspar. The results of the test are shown by the diagram in figure 4.

The figure shows that the increase in soda content causes the deformation eutectic almost to disappear and leaves only the rate of deformation to indicate that such an eutectic exists. The rates of deformation of the mixtures are somewhat faster than those of the pure potash feldspar-quartz mixtures but are much slower than those of the pure soda feldspar-quartz mixtures.

GENERAL CONCLUSIONS ON FELDSPAR-QUARTZ DEFORMATION TESTS.

From these deformation studies it appears that pure potash feldspar may be expected to deform at about cone 10 and that adding 10 per cent of quartz lowers the deformation temperature to a noticeable extent but does not increase the rate of deformation.

If a small proportion of the potash feldspar is replaced by soda feldspar (2 per cent Na_2O), the mixtures with quartz do not in any case begin to deform at a lower temperature than the feldspar. However, a mixture of 95 per cent feldspar and 5 per cent quartz begins to deform at the same temperature as pure feldspar but completes deformation in slightly less time. A 90 to 10 mixture begins to deform at a noticeable interval after the pure feldspar and the 95 to 5 mixture, but completes deformation at the same time as the 95 to 5 mixture. Thus a 90 to 10 mixture has a greater rate of deformation

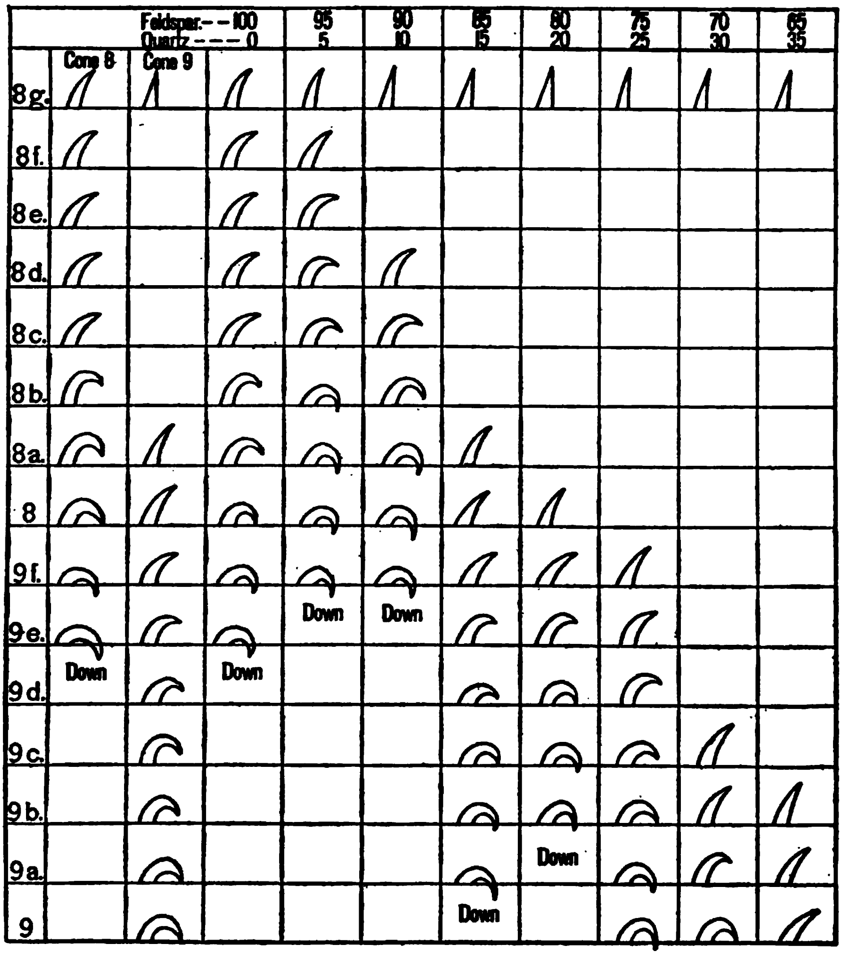

FIGURE 4.—Deformation of commercial feldspar-quartz cones.

than the potash-soda feldspar itself. All mixtures of this feldspar with quartz show a tendency to deform more rapidly after deformation begins than does the pure feldspar.

The soda feldspar-quartz mixtures show no evidence of having lower deformation temperatures than pure soda feldspar, and increasing the quartz content of the mixture increases with noteworthy regularity the temperature at which deformation begins. However, a mixture of 75 per cent soda feldspar and 25 per cent quartz deforms more rapidly after deformation begins, and in all mixtures of soda feldspar and quartz, and also pure soda feldspar, deformation proceeds much more rapidly after it begins than in potash or potash-soda feldspars or any of their mixtures with quartz.

CAUTION REGARDING INTERPRETATION OF THE ABOVE DATA.

The above data must not be interpreted as indicating that commercial feldspars containing quartz are equal in value to pure feldspars. Any adulteration with quartz means that a larger amount of the feldspar-quartz mixture must be used in order to furnish the necessary quantity of feldspar for fluxing. On the other hand, the percentage of quartz which is added to the body as ground flint must be reduced by the amount of quartz added with the feldspar. For example, a body having the composition 20 per cent feldspar, 35 per cent flint, and 45 per cent clay is to be made, using a commercial feldspar which contains 80 per cent feldspar and 20 per cent quartz. In order to introduce the proper amount of pure feldspar, 20 per cent, 25 per cent of commercial feldspar (20 parts feldspar plus 5 parts quartz) must be used. The 5 per cent of quartz added with the feldspar must be deducted from the 35 per cent of flint, leaving 30 per cent of flint to be added as such. The actual working recipe of the above body would be 25 per cent commercial feldspar, 30 per cent flint, 45 per cent clay.

This shows that the adulteration of feldspar by quartz does not in any way make the feldspar more active in the pottery mixtures unless the mixture contains no flint.

DEFORMATION TESTS OF FELDSPAR-BERYL MIXTURES.

The results of tests of feldspar-beryl mixtures and of feldspar-muscovite mixtures, which have already been published in Bulletin 53 [a] of the bureau, are described in the following:

> The presence of crystals of beryl in the pegmatite dikes, and the fact that they are found chiefly associated with the parts richest in feldspar, made it necessary to ascertain what effect this mineral exerts on the industrial value of feldspar.

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[a] Watts, A. S., Mining and treatment of feldspar and kaolin in the southern Appalachian region: Bull. 53, Bureau of Mines, 1913, pp. 28-30.

For this purpose, a series of mixtures of microcline and beryl was prepared from the two minerals ground separately to 200-mesh fineness, and made into cones. These cones were tested in the same manner as were the feldspar-quartz and feldspar-muscovite mixtures, and the results are shown in figure 6.

Beryl has the following composition, $3BaOAl_2O_3.6SiO_2.\frac{1}{2}H_2O$.

The mixture containing 20 per cent beryl begins to deform as cone 6 touches the plate. The mixtures containing 15 per cent, 10 per cent, and 5 per cent beryl follow quickly after the mixture containing 20 per cent beryl. The feldspar-beryl series continue to deform in the order in which they start, the first to begin deforming being the first to touch the plate. The entire series deforms completely within less than one-cone temperature range, starting at cone 6, touching and extending to cone 7, not quite touching the plate. This series indicates that the deformation temperature decreases with increase of beryl content, at least to 20 per cent, where the series ended. As a test cone of pure beryl was tested with this series and was heated up to cone 8 without deforming, a eutectic is indicated between feldspar and beryl. A study of the fired cones indicates slightly more deformation in the mixture containing 15 per cent beryl, but as this was not apparent in the process of deformation, its influence is difficult to determine.

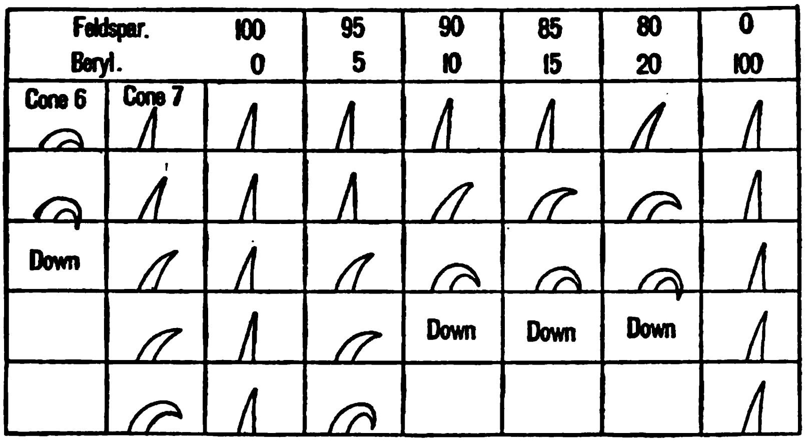

FIGURE 5.—Deformation of feldspar-beryl cones.

DEFORMATION TESTS OF FELDSPAR-MUSCOVITE MIXTURES.

As muscovite (white mica) is present in nearly every pegmatite in the district investigated, it is important to know what effect it exerts on the deformation point and color of the feldspar. For this purpose a series of feldspar-muscovite mixtures was made and tested in the same manner as the feldspar-quartz mixtures. The muscovite and the feldspar were both ground to pass a 200-mesh sieve. The results of this test are shown in figure 6. These results are especially interesting in view of the fact that muscovite has the composition $K_2O.3Al_2O_3.6SiO_2$, and contains the same elements as feldspar, but by virtue of its higher alumina content is more difficultly fusible, being reported by Rieke [a] as deforming with cone 13.

In the figure it will be noted that the mixture containing 5 per cent of muscovite begins to deform before any other mixture tested. The order in which the various mixtures deform is regular, the mixture containing 20 per cent muscovite being the last to begin to deform. The rate of deformation, however, appears to be just the reverse of this, as the mixture containing 20 per cent muscovite deforms until it touches the plate before any other of the series. Note also that as the mixture containing 5 per cent muscovite, which has the slowest rate of deformation, touches the plate the pure feldspar shows the first indication of deformation. Thus it appears that additions of finely ground muscovite to a microcline feldspar lowers the deformation temperature, and the rate of deformation increases with the increase in muscovite.

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[a] Rieke, R., Sprechsaal, Bd. 42, 1908, p. 578.

The influence of muscovite upon the color of the feldspar is really the most important consideration in the presence of muscovite, although the proportions present in any deposit known would hardly average 1 per cent. A specimen containing this percentage is scarcely distinguishable from pure feldspar. The tint produced by the muscovite is a pale drab, which is the same as is imparted in porcelains by the ball clay, and hence would not be noticed.

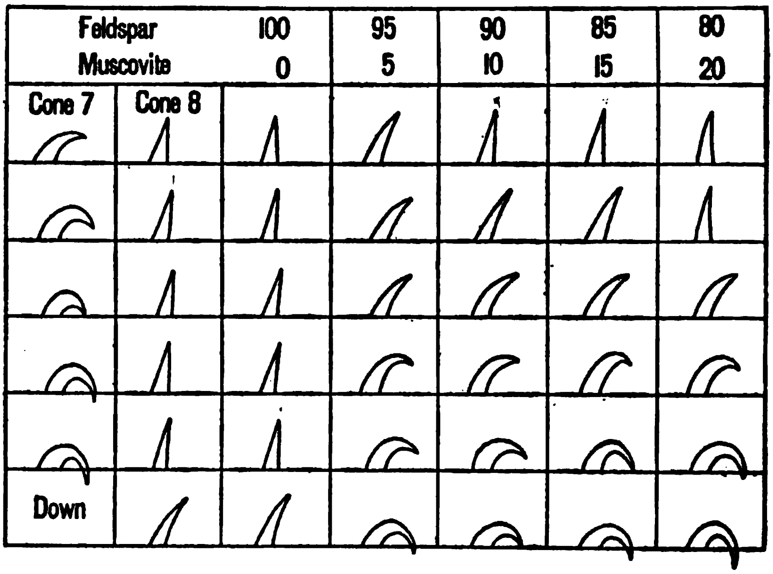

FIGURE 6.—Deformation of feldspar-muscovite cones.

DEFORMATION TESTS OF FELDSPAR-BIOTITE MIXTURES.

As biotite (black mica) is a constituent of practically every pegmatite dike and is considered by users of feldspar as an injurious, if not the most injurious, associate mineral, it is important to know the effect of biotite on the pyrometric properties of feldspar.

Biotite has the composition $K_2O.4MgO.2Al_2O_3.6SiO_2$, in which MgO may be replaced in part by FeO and Al_2O_3 by Fe_2O_3, the depth of color being determined by the extent of this replacement.

A series of feldspar and biotite mixtures was prepared by pulverizing each of the minerals until it passed a 200-mesh bronze sieve, mixing them in the proper proportions, and regrinding each mixture carefully to insure as intimate a mixture as possible. The mixtures were made into cones of standard dimensions and these were tested against standard pyrometric cones for deformation temperature and rate of deformation. The results of the tests are shown in figure 7.

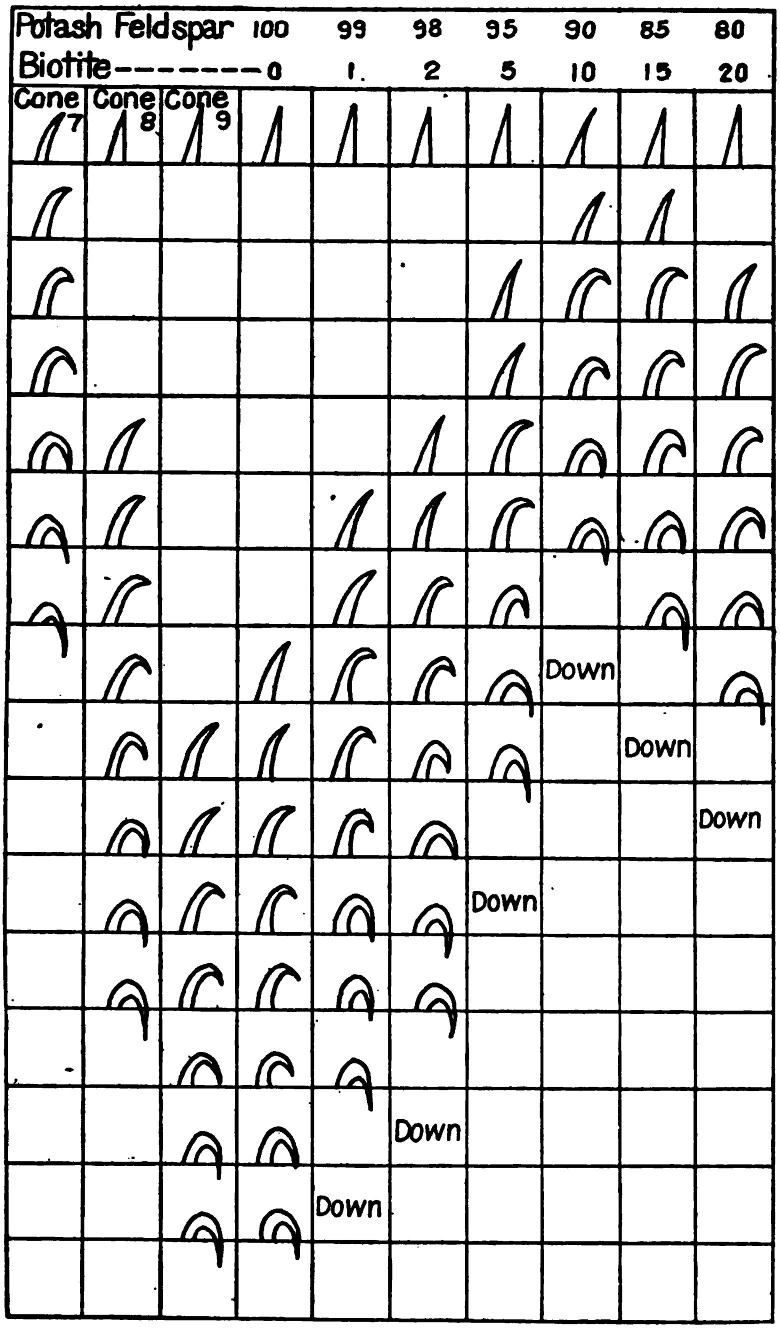
Potash Feldspar 100 99 98 95 90 85 80
Biotite--------0 1. 2 5 10 15 20
Cone 7
Cone 8
Cone 9
Down
Down
Down
Down
Down
Down

FIGURE 7.—Deformation of feldspar-biotite cones.

The results indicate that a eutectic mixture is formed with about 90 per cent feldspar and 10 per cent biotite. The feldspar alone deformed at about cone 9, whereas the eutectic mixture deformed at about cone 7, indicating that biotite causes a pronounced lowering of the deformation temperature. The rate of deformation is not noticeably affected. The coloring action of the biotite is a complete barrier to the use of biotite-bearing feldspar in most ceramic industries, as 1 per cent of biotite colors the fired feldspar a pronounced gray and 2 per cent produces a dark gray-brown color. The mixtures containing 5 per cent biotite show a tendency to boil when deformation begins, a characteristic of mixtures containing an excess of magnesium.

EFFECT OF KAOLIN ON PROPERTIES OF COMMERCIAL FELDSPAR.

The presence of kaolin and kaolinized material in commercial feldspar makes a knowledge of the effect of kaolin on the properties of the feldspar important. Such an investigation has been made by Hewitt Wilson, ceramic engineer, in preparing data for a thesis at Ohio State University, and those parts of the paper [a] which bear on this subject are given here.

DEFORMATION TESTS OF FELDSPAR-KAOLIN MIXTURES.

KAOLINIZATION OF FELDSPAR AND SIGNIFICANCE.

The kaolin impurity in most commercial feldspars averages from 1 to 3 per cent and usually is the result of the decomposition of more exposed portions of the bed. A description of this "decomposition of feldspar and the recombination of a portion of the decomposition products of kaolin" has been given by Watts.[b] Briefly it is this:

The molecular formula for orthoclase or microcline feldspar is $K_2O.1Al_2O_3.6SiO_2$. By water solution the K_2O is lost, leaving $Al_2O_3.6SiO_2$ as the insoluble decomposition products. The Al_2O_3 and $2SiO_2$ of this recombine with the absorption of $2H_2O$ to form kaolin, leaving 4 molecules of silica as free quartz. Thus the presence of kaolin and quartz impurities in a bed of feldspar is partly accounted for.

The increase of the combined water and the decrease of the potash content are thus indicators of the degree of kaolinization. As the water content increases, the deformation temperature also increases. By plotting the water alkali curve alongside this other, a corresponding deformation temperature can be obtained for each percentage of alkali in the feldspar. We, therefore, may say that generally the more kaolinized is the feldspar—that is, the higher the water and lower the alkali content—the higher will be the deformation temperature. However, when the feldspar contains less than 16 per cent kaolin, it has been found that there are indications of the formation of a eutectic, so that the rise of the deformation temperature is not as rapid as with higher percentages of kaolin.

Simonis (Sprechsaal, 1907, vol. 2) gives a deformation temperature determination for Zettlitz kaolin-feldspar mixtures and it was decided to check this curve with our kaolin and feldspar.

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[a] Wilson, Hewitt, Deformation study of feldspar-kaolin mixtures: Trans. Am. Cer. Soc., vol. 15, 1913, pp. 217-232.

[b] Watts, A. S., Mining and treatment of feldspar and kaolin in the southern Appalachian region: Bull. 53, Bureau of Mines, 1913, p. 16.

Watts[a] found that there was an apparent eutectic with 90 per cent feldspar and 10 per cent quartz. As most commercial feldspars contain both quartz and kaolin impurities it would be nearer actual working conditions to have both present in this study, after the mixture of feldspar with quartz and with kaolin had been investigated separately.

METHOD AND PROCEDURE.

The chemical analysis of the feldspar and also of the theoretical microcline are as follows:

	Feldspar used.	Theoretical microcline.
Moisture....per cent..	0.17	.....
SiO_2....do....	65.37	64.75
Al_2O_3....do....	17.92	18.34
TiO_2....do....	Trace.	.....
Fe_2O_3....do....	.02	.....
CaO....do....	.17	.....
MgO....do....	Trace.	.....
K_2O....do....	13.05	16.90
Na_2O....do....	2.10	.....
	98.80	99.99
Specific gravity....	2.57	2.56

The purest kaolin obtainable was used.

	Kaolin No. 83.	Theoretical kaolin.
Moisture....per cent..	13.22	13.90
SiO_2....do....	46.67	46.30
Al_2O_3....do....	39.07	39.80
Fe_2O_3....do....	.11	......
TiO_2....do....	.02	......
CaO....do....	Trace.	......
MgO....do....	Trace.	......
Na_2O....do....	.11	......
K_2O....do....	.25	......
	99.45	100.00

The crude, unwashed clay was blunged in a small household churn, passed through a 200-mesh screen to remove all the larger quartz and mica particles, and then sized in a Schultz elutriation apparatus * * *.

Four sizes of grain were separated, dried, and their average size determined with a microscope:

Jar No. 1=0.0032 to 0.0040 inches.
Jar No. 2=0.0024 to 0.0032 inches.
Jar No. 3=0.0016 to 0.0024 inches.
Jar No. 4=0.0009 to 0.0016 inches.

Most of the clay grains were taken from jar No. 3, and after the relative size of grain study this size was used altogether for all the cones.

The feldspar and kaolin ingredients of the cone mixtures were weighed out * * * and the two were mixed dry by passing twice through a 150-mesh screen and enough dextrine added to permit its being formed * * * into a standard size cone * * *. Each cone was stamped with its serial and clay content number and baked in a constant temperature oven at 109° C.

From 24 to 27 hours were used in reaching cone 8; rapid firing maintained until cone 6 to 7 was reached and then several hours intervening until cone 8 should start.

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[a] Watts, A. S., Op. cit., pp. 26, 27, 28.

DATA AND RESULTS.

To determine the effect of size of grain of the kaolin, a series was made up of 0.2, 5, 7.5, and 10 per cent of each of the sizes Nos. 2, 3, and 4 of kaolin and fired as a preliminary burn. No difference could be distinguished between the three, and so kaolin No. 3 was used throughout the rest of the determination.

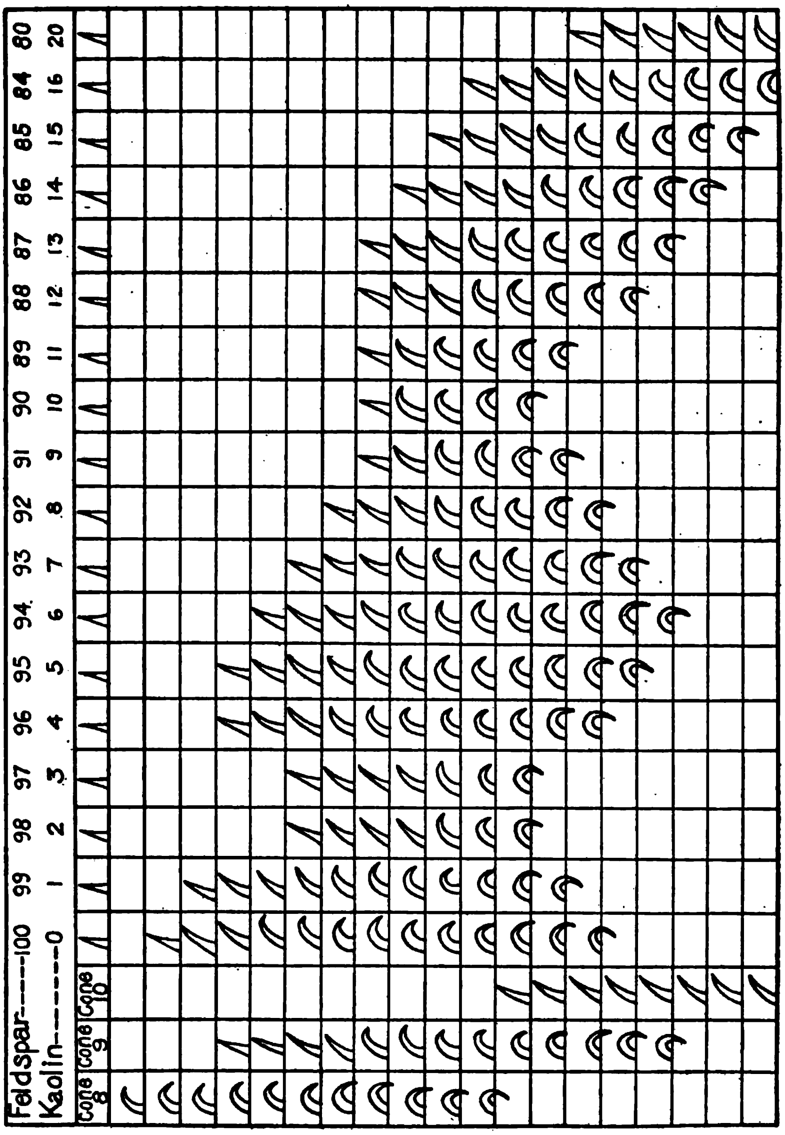
Feldspar——100 99 98 97 96 95 94 93 92 91 90 89 88 87 86 85 84 80
Kaolin——0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 20
Cone 8
Cone 9
Cone 10

FIGURE 8.—Deformation of kaolin-feldspar cones.

Kaolin was added to feldspar in 1 per cent intervals, from 0 to 16 per cent. Beyond this the kaolin percentages were 25, 30, 35, 40, and 45. The average of 9 burns is given in figure 8.

This chart indicates that—

1. The pure feldspar deforms between cone 8 and cone 9, being closer to the latter.
2. Around 2 and 3 per cent kaolin the start of deformation is late, the rate is fast, and the end is before that of pure feldspar.
3. At 5 and 6 per cent the rate decreases until it is about that of the pure feldspar, but the start and end of deformation is behind that of the latter.
4. In the 9 to 11 per cent region there is another slow starting, a rapid rate, and quick finish to deformation. The rate here is faster than any other.
5. Beyond 10 per cent kaolin, normal conditions are gradually resumed, the start and finish progressing toward higher temperatures with the increase of kaolin.

Cones in which the kaolin impurity varies only by 1 per cent do not show much difference in their deformation. Hence regions, instead of definite percentages, must be used in terming these indicated eutectics.

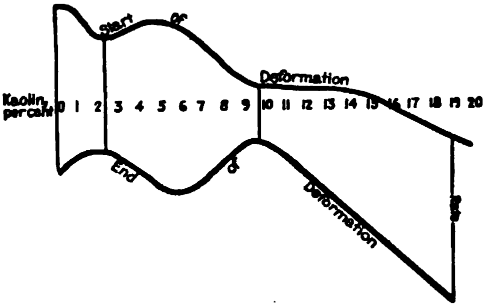

FIGURE 9.—Diagram showing relation of rate of deformation to proportion of kaolin. Vertical distance between lines represents rate of deformation of pure feldspar.

Figure 9 shows in a more general way the rate of deformation, that being designated by vertical distances between the two curves. The normal rate—that is, that of pure feldspar—is represented by the vertical distance between the two dotted lines dropping to the right as the kaolin content increases.

CONCLUSIONS.

The results of these two charts show that there are two indicated deformation eutectics, the lesser in the region of 2 to 3 per cent kaolin and 98 to 97 per cent feldspar, and the greater at 9 to 11 per cent kaolin and 91 to 88 per cent feldspar. Correspondingly, 5 to 6 per cent kaolin and 95 to 94 per cent feldspar is a region which may be termed a deformation compound. When we speak of regions, it is meant that in the limits given there is a definite percentage at the maximum or minimum point which should be termed the deformation eutectic, or compound, but that it has not been accurately determined.

REFIRING.

A final determination was made to this phase of the study by grinding up the deformed cones to pass 150 mesh, mixing with dextrine, reforming into cones and firing again; 0, 2, 4, 6, 7, 5, 10, 12.5 per cent of kaolin were used. The results as given in figure 10 in general check the above results, the deformation, however, taking place from two to three cones lower—close to cone 6. Pure feldspar started about the same time as the others, but was slow in deforming. Two, 4, 7.5, and 10 per cent were practically the same and deformed more rapidly than pure feldspar. Six per cent kaolin was slightly behind 2 and 10 per cent and dropped more like 0 per cent, thus indicating the higher region of 4 to 6 per cent.

KAOLIN-FELDSPAR-QUARTZ TESTS.

Kaolin was added to a 1 to 9 mixture of quartz-feldspar in the percentages 0, 2, 4. 6, 8, and 10. The results of two burns are given in figure 11. The deformation took place with cones 8 and 9, the same as with kaolin and feldspar alone. With 8 per cent kaolin went the most rapid deformation, 10 per cent and 0 per cent kaolin came next, with a lesser rate, leaving 2 to 4 per cent as the "high" region and the slowest to deform.

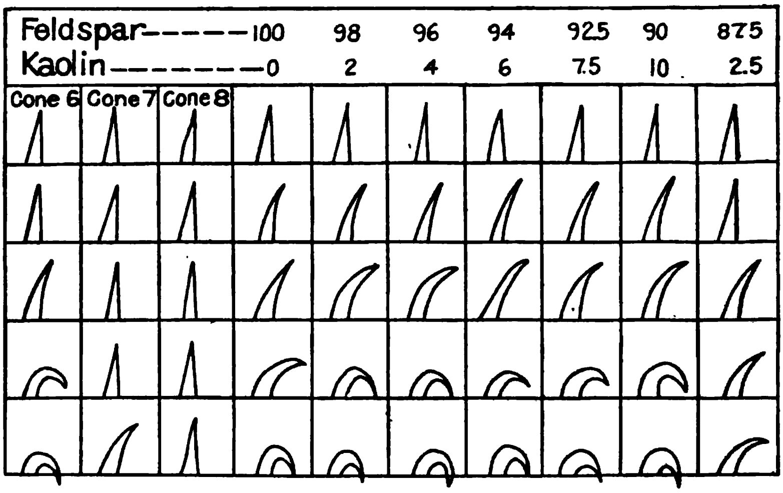
Feldspar——100 98 96 94 92.5 90 87.5
Kaolin——0 2 4 6 7.5 10 2.5
Cone 6
Cone 7
Cone 8

FIGURE 10.—Deformation of refined kaolin-feldspar cones.

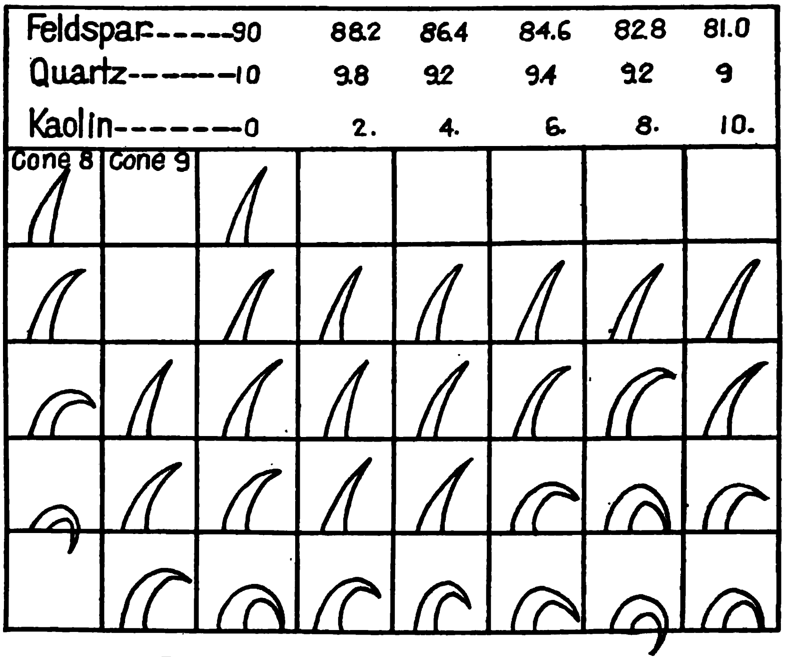
Feldspar——90 88.2 86.4 84.6 82.8 81.0
Quartz——10 9.8 9.2 9.4 9.2 9
Kaolin——0 2. 4. 6. 8. 10.
Cone 8
Cone 9

FIGURE 11.—Deformation of kaolin-feldspar-quartz cones.

Hence, in a general way, the feldspars with both quartz and kaolin impurities may be made to deform with and before pure feldspar, especially when in the region of 8 to 10 per cent kaolin, 9.2 to 9 quartz, and 82.8 to 81 per cent feldspar.

MIXTURES HIGH IN KAOLIN.

Dr. Simonis (Sprechsaal, 1907, vol. 2) gives the following table for the deformation of kaolin-feldspar mixtures:

Deformation points of kaolin-feldspar mixtures.

No. of mixture.	Proportions in mixture.		Deformation point, cone—
	Zettlitz kaolin.	Feldspar.	
	Per cent.	*Per cent.*	
67	15	85	9
74	30	70	14
80	45	55	26+
85	55	45	28
89	70	30	31+
92	85	15	33 to 34

As is shown by figure 12, we partly checked this with our kaolin and feldspar, the slight variations being probably due as much to furnace irregularities as to anything else. Standard sized cones were made of the different mixtures and tested with standard cones in a small gas-fired muffle furnace.

In the figure the dotted lines show where our results disagree with those of Simonis. Notice the rise in deformation of 12 cones between the limits of 30 to 40 per cent kaolin.

GRAPHIC GRANITES AS A SOURCE OF FELDSPAR.

As the exposed deposits of pure feldspar in the United States are rapidly being worked out and the locating of new deposits of pure material is a matter of more or less uncertainty, it seems wise to seriously consider the available sources of feldspar which is not pure but contains no impurity that would make the feldspar unfit for ceramic uses. The most fruitful source of such investigation is the graphic granites or graphic pegmatites. The pure feldspar has been obtained from isolated lenses in these pegmatite dikes, and in mining it vast quantities of pegmatite rich in feldspar and containing little or no impurity, except quartz, were quarried. This was rejected as waste. When the lenses of pure material were becoming exhausted, the operator began to work over these waste heaps and also to quarry the walls adjoining the pure feldspar lenses, and he found there much material free from other impurity except quartz. This material was sorted, and the portion in which the quartz content did not exceed 10 or 15 per cent was accepted and mixed with the pure feldspar. No serious difficulty resulted from the replacement of 5 or 10 per cent of the feldspar by quartz, as this amount of variation in the ordinary pottery body might often occur through the use of material in which an excess of moisture existed.

However, each year the supply of available pure feldspar becomes less, and also the part of the graphic granites which is richest in feldspar is being used up, leaving a poorer assortment from which to select.

Owing to the gradual hardening of the commercial grade of New England feldspars, which is not due to any change in the feldspar itself, but merely to the increased quartz content, many users have turned to other sources of supply, thus fortunately leaving the New England feldspars to those manufacturers who found their use essential to proper color in their wares. This is especially true of the Maine feldspars, which are recognized as being superior in color to any other American feldspar except the North Carolina feldspars, the cost of which is prohibitive in many industries.

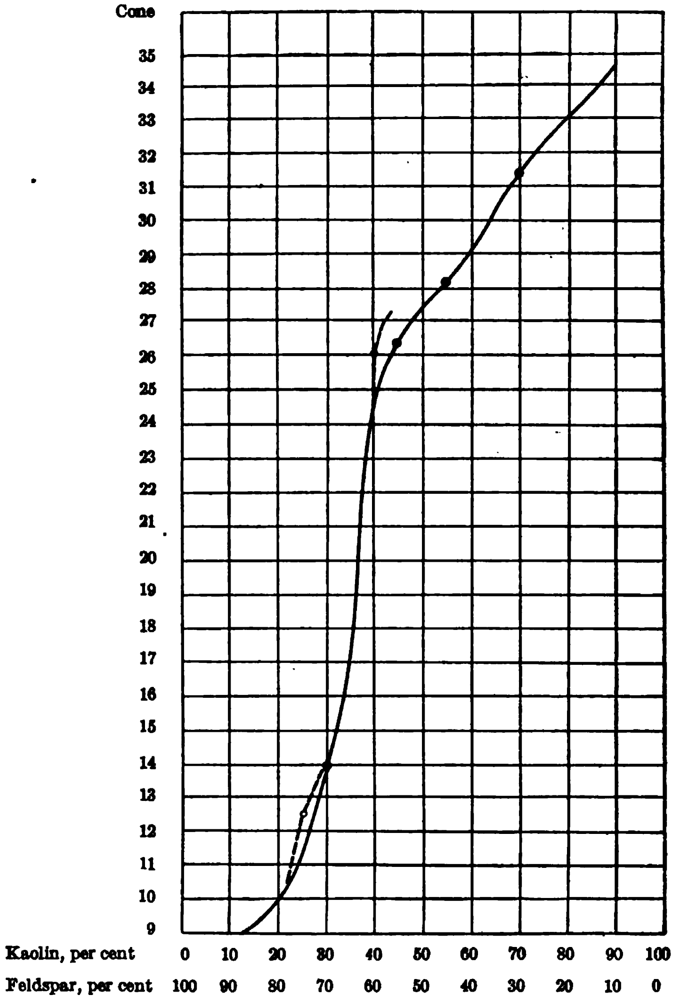

FIGURE 12.—Deformation curve of kaolin-feldspar series. After Simonis. Dotted lines show where results of Wilson's tests disagree with those of Simonis.

PROPERTIES OF GRAPHIC GRANITES.

Graphic pegmatites, or graphic granites as they are generally termed, do not differ in essential constituents from ordinary pegmatite, except that the associate quartz is distinctly crystalline, as is shown in Plate I, *B*. The remarkable similarity of the quartz crystals to Chinese lettering has led to the application of the term "graphic granite" or "Schriftgranit," as it is called in German literature.

The value of the graphic granites for ceramic purposes naturally depends on the amount of impurity present and it is worthy of note that when the feldspar and quartz are intercrystallized as in this graphic form the amount of other minerals present is much less than in other forms of pegmatite or granite. As quartz is the chief associate mineral, its effect on the deformation point of the feldspar is of importance to the ceramist.

FELDSPAR-QUARTZ RATIO IN GRAPHIC GRANITES.

Vogt[a] has offered the theory that in graphic granite the quartz and feldspar are present in eutectic proportions. He presents as evidence the following analyses of graphic granites and their recalculation into feldspar and free quartz contents.

Composition of graphic granites.

	No. 1.	No. 2.	No. 3.	No. 4.
Composition:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	74.04	74.00	73.82	74.47
Al_2O_3	14.44	14.31	14.44	15.13
CaO	.33	.39	.35	.72
K_2O	9.36	9.02	8.90	7.06
Na_2O	2.01	2.42	2.45	2.01
Feldspar	74.7	75.3	75.3	72.7
Free quartz	25.3	24.7	24.7	27.3

In conclusion he says:

> When the potash feldspar is in excess, the proportions of feldspar and quartz in graphic granites are absolutely constant or only very slight variable * * * From this we conclude with absolute certainty that the graphic granite is a eutectic mixture and has a composition approaching 74 per cent feldspar and 26 per cent quartz.

Teall[b] concludes that the graphic granite represents the eutectic between feldspar and quartz.

Johnson[c] concludes that the feldspar-quartz content in graphic granites has a definite ratio, dependent upon the type of feldspar present. When the feldspar is orthoclase the molecular ratio of feldspar to quartz is 2:3. When the feldspar present is plagioclase the molecular ratio is 1:2. When the feldspar present is albite the molecular ratio is 1:3.

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[a] Vogt, J. H. L., Die Silikatschmelz-lösungen, 1904, pp. 117-128.

[b] Teall, J. J. H., British petrography, 1888, p. 402.

[c] Johnson, H. E., Geologiska föreningens Förhandlinger, Bd. 27, 1905, p. 119.

Bygden[a] concluded from a study of many analyses that the type of feldspar present bears no definite relation to the feldspar-quartz ratio. He believes that a definite feldspar-quartz ratio does exist in most graphic granites, but thinks it is not so simple as Vogt and Johnson imagine.

Bastin,[b] after considering the data and opinions of other investigators, compiled a table of mineral compositions of graphic granite in which he included not only all available foreign data but also the compositions of three Maine graphic granites. From a study of these he finds that even among graphic granites whose feldspars are almost identical in composition, there are considerable variations in the feldspar-quartz ratio. Bastin's table of graphic granite compositions is included as analyses D to G in the table following.

VARIATION IN GRANITES THROUGHOUT A GIVEN DISTRICT.

The subject of chief interest to users of feldspar is the possible variation of graphic granites throughout a given district, both as regards ratio of feldspar to quartz and also as regards the chemical composition and physical behavior of the feldspar component of the graphic granites.

In the following table samples A, B, and C were collected by A. S. Watts, of the Bureau of Mines, and were analyzed by A. C. Fieldner of the bureau. Samples D to G were collected by the United States Geological Survey and were analyzed by George Steiger in the laboratory of the Geological Survey.

Composition of New England graphic granites.

CHEMICAL COMPOSITION.

	A.[c]	B.[c]	C.[c]	D.[d]	E.[d]	F.[d]	G.[d]
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	73.89	74.34	74.53	73.89	73.92	72.76	71.00
Al_2O_3	14.33	14.45	14.26	13.75	14.26	15.47	16.31
CaO	Trace.	Trace.	Trace.	None.	None.	.19	.22
MgO	do.	do.	do.	do.	do.	None.	None.
BaO	None.	None.	None.				
Fe_2O_3	.16	.14	.16	.26	.30	([e])	([e])
K_2O	9.02	8.63	8.55	9.00	8.99	9.28	8.66
Na_2O	2.14	2.00	2.25	2.10	2.06	2.35	3.44
H_2O	.33	Trace.	.30	.24	.11	.15	.12

CALCULATED MINERAL COMPOSITION.

	A.	B.	C.	D.	E.	F.	G.
Potash feldspar	53.4	51.1	50.6	54.4	55.2	55.0	51.4
Soda feldspar	18.2	16.9	19.1	18.5	18.5	20.0	29.1
Lime feldspar						1.0	1.0
Free quartz	26.9	29.7	28.7	27.1	26.3	23.0	17.6
Other constituents	1.5	2.3	1.6	Trace.	Trace.	1.0	.9
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

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[a] Bygden, A., Über das quantitative Verhältniss zwischen Feldspat und Quarz in Schriftgraniten: Bull. Geol. Inst. Univ. Upsala, vol. 7, 1904, pp. 1-18.

[b] Bastin, E. S., Geology of the pegmatites and associated rocks of Maine, including quartz, feldspar, mica, and gem deposits: U. S. Geol. Survey Bull. 445, 1911, pp. 39-42, 124-125.

[c] Bureau of Mines samples.

[d] Geological Survey samples.

[e] Fe_2O_3 included with Al_2O_3.

Sample A.—Fine-grained graphic granite (see Pl. I, *B*) from newly opened quarry of Maine Feldspar Co., east slope of Mount Ararat, Topsham, Maine.

Sample B.—Medium-grained graphic granite (see Pl. I, *B*) from Wm. Willis quarry, Cathance, Maine.

Sample C.—Coarse-grained graphic granite (see Pl. I, *B*) from Golding Sons Co. quarry, Georgetown Peninsula, Maine.

Sample D.—Coarse graphic granite, Fisher's quarry, Topsham, Maine. Quartz layers about 1 inch across and feldspar layers about 4 inches across.

Sample E.—Moderately coarse graphic granite, Fisher's quarry, Topsham, Maine. Quartz layers about 0.05 inch across and feldspar layers about 0.15 inch across.

Sample F.—Fine grained graphic granite from Kinkle's feldspar quarry, Bedford, West Chester Co., N. Y. Quartz layers about 0.03 inch across and feldspar layers about 0.08 inch across.

Sample G.—Graphic granite from Andrews quarry, Portland, Conn. Quartz layers vary but average not more than 0.02 inch across. The feldspar layers average nor more than 0.05 inch across. Some areas of pure feldspar in the sample increase the the feldspar content shown by the analysis above what a graphic granite of this fineness should yield.

Study of the analyses A, B, C, D, and E, all of which are from the chief feldspar-producing district of Maine, shows no greater difference in chemical composition than would be expected in samples taken from different places in a single quarry. The maximum variation in potash content is 0.47 per cent, in soda 0.25, in total alkali only 0.53, in alumina 0.70, and in silica 0.64 per cent. The calculated mineral compositions indicates that the maximum variation in free silica content is only 3.4 per cent.

From the foregoing it appears that the statement of Vogt regarding the ratio of feldspar and quartz seems to hold for Maine graphic granites. A comparison of the calculated mineral compositions indicates that there is no relation between the variation in free quartz content and the size of quartz particles.

RELATION BETWEEN PYROMETRIC BEHAVIOR AND FELDSPAR CONSTITUENTS.

The next problem was to determine the relation between the pyrometric behavior of the graphic granites and of their feldspar constituents. For this study, three graphic granites, A, B, and C, were selected which grade from a very fine to a very coarse grained granite. The quartz in all three samples was of the smoky variety and the feldspars are indicated by optical analyses to be microclines with small intergrowths of albite.

PREPARATION OF SAMPLES.

The three samples were photographed (Pl. I, *B*) and then each sample was divided into two equal parts; one part was pulverized as pegmatite and the other part carefully cleaned of all free quartz and pulverized as pure feldspar. In each case the pulverized material was ground dry to pass a 200-mesh sieve, mixed with a small amount of dextrine, and molded in the plastic state into cones similar to standard pyrometric cones. These cones were tested as follows: (*a*) For the deformation temperatures and rates of deformation of the graphic granites as such; (*b*) for the deformation temperatures and rates of deformation of the pure feldspar components; (*c*) for the relation between the graphic granites and mixtures of their feldspar components and known proportions of pulverized quartz. The quartz used in this last test was quartz sand pulverized dry to pass a 200-mesh sieve.

RESULTS OF TESTS.

The relative pyrometric behavior of the graphic granites and their feldspar components is shown in figure 13.

The diagram shows that at least in the case of these graphic granites of Maine the deformation temperature lies well beyond that of their feldspar components. The first of the feldspars to commence deformation was C, followed within a few degrees by feldspars B and A. The feldspars all deform at about the same temperature as cone 8, feldspar C deforming at a temperature slightly lower and feldspars A and B at one slightly above cone 8. The rate of deformation of the three feldspars varies slightly, that of feldspar C, which begins to deform first, being the highest. Feldspars A and B both deform at the same rate as cone 8.

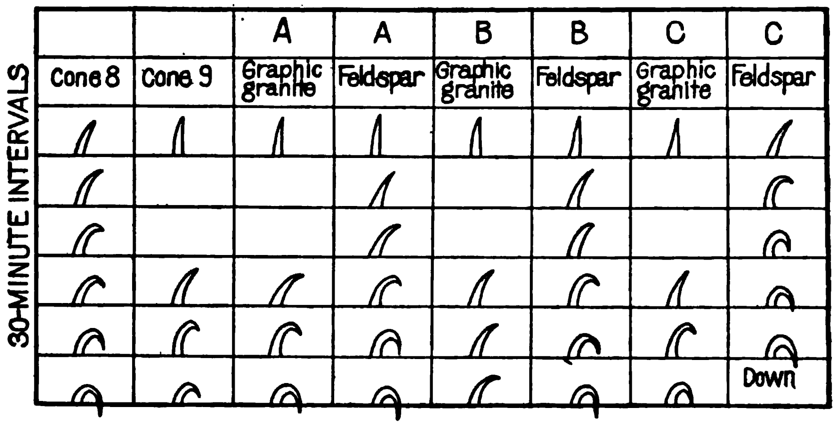

FIGURE 13.—Deformation of graphic granites and their feldspar components.

The three graphic granites of which these three feldspars formed a part do not deform until cone 9, and furthermore do not deform in the same order as the feldspars, but follow the order of the calculated free quartz content. Graphic granite A, which has a calculated free quartz content of 25.8 per cent, begins to deform noticeably ahead of the other two granites and completes deformation distinctly ahead of them. Graphic granites B and C, carrying respectively 27.6 per cent and 27.4 per cent of free quartz, begin to deform at the same temperature, but C deforms more quickly than B and is completely deformed when B is not more than half deformed.

The results of the analyses show that graphic granite C has the lowest alumina content and the highest soda content, both of which factors tend to favor rapid deformation in the pure feldspar. However, the small excess of free quartz in this granite more than counteracts the effect of the more fusible feldspar and causes the granite to deform at a higher temperature than graphic granite A, which contains slightly less soda and slightly more alumina but contains 1.6 per cent less free quartz.

Graphic granite B, which is the richest in free quartz and contains the highest percentage of alumina and the lowest percentage of soda, is the most refractory of the three samples, and its feldspar component is more refractory than that contained in either of the other two graphic granites.

Thus it is clear that a slight variation in composition may greatly change the temperature and rate of deformation of a graphic granite.

It must be remembered, however, that the three graphic granites tested are so similar that in a commercial plant the difference in pyrometric behavior would hardly be noticed.

The main point brought out by this experiment is the fact that graphic granites high in potash and low in soda and containing no lime, of which the graphic granites of Maine are examples, deform at temperatures distinctly higher than do their feldspar components. Hence they are not deformation eutectic mixtures of feldspar and quartz. Whether these graphic granites are true eutectic mixtures, in that the ratio of feldspar to quartz represents the saturation point of each in the other so that both may solidify at the same time, is a question which this study was not designed to prove.

DETERMINATION OF QUARTZ CONTENT.

The determination of the quartz content in the graphic granites by synthesis resulted as follows:

Graphic granite A was very fine grained. A block of this material was crushed and then cleaned as completely as possible of free quartz. The fact that the quartz present was of the smoky variety made its detection less difficult than would otherwise be the case. The pure feldspar was pulverized to pass a 200-mesh sieve and a series of mixtures with pulverized quartz prepared containing 5 to 35 per cent quartz. The mixtures were molded into cones of standard dimensions. This series was placed on a fire-clay slab, together with a specimen of the original graphic granite A and also a specimen of the pure feldspar A.

The pure feldspar deformed with cone 8. The graphic granite A deformed slightly above cone 8 and simultaneously with the mixture of feldspar A and 25 per cent quartz. A comparison of this data with the calculated norm composition shows that the discrepancy is not very great.

Graphic granite B was of medium size grain. A block of this material was crushed, cleaned, and pulverized in the same manner as graphic granite A. Specimens of the pure feldspar and the graphic granite and a series of feldspar-and-quartz cones were prepared and tested.

Pure feldspar B deformed with cone 8. Graphic granite B deformed with the mixture consisting of 70 per cent feldspar and 30 per cent quartz and at the temperature of cone 9. A comparison of this data with the calculated norm composition indicates a discrepancy of 2.4 per cent, as the calculated content of free quartz is 27.6 per cent.

Graphic granite C was coarse grained. A block of this material was prepared and tested in a manner similar in all respects to that followed with graphic granites A and B.

Pure feldspar C deformed midway between cones 7 and 8. Graphic granite C deformed between cones 8 and 9, but nearer cone 9 temperature. It deformed with the mixture of feldspar C and 30 per cent quartz. A comparison of this data with the calculated norm composition shows the synthetic mixture to be 2.6 per cent high.

This method of determining the quartz content of a pulverized feldspar is shown to be perfectly practical within general limits, but can not be depended on for determinations closer than 2 or 3 per cent. This discrepancy is possibly in part due to the fact that the quartz used in the synthetic mixtures was finer grained than the quartz contained in the ground graphic granite. This fact was proven by microscopic study of the fused cones, although the powdered materials were all thought before use to be of sufficiently uniform fineness.

In nature graphic granite is a mixture of feldspar and quartz in intimate crystalline relation, but both exist as distinct minerals. These graphic granites must be reckoned as mixtures of feldspar and quartz, which fortunately are remarkably constant for graphic granites containing feldspars free from lime and high in potash and low in soda. If the user of graphic granite will recalculate it in terms of feldspar and quartz and introduce it as such, much of the difficulty arising from its use will be overcome.

NORMATIVE COMPOSITION OF GRAPHIC GRANITES.

The compositions of 18 graphic granites, calculated into their mineral components as norms,[a] is given in the table following. This list, with the exception of Nos. 3, 4, 8, and 14, is discussed by Bastin.[b]

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[a] For a discussion of methods of calculating the normative composition of a rock from the actual composition, as shown by chemical analysis, and the significance of the relationship, see Clarke, F. W., The data of geochemistry, U. S. Geol. Survey Bull. 491, 1911, pp. 404–406.

[b] Bastin, E. S., Geology of the pegmatites and associated rocks of Maine: U. S. Geol. Survey Bull. 445, 1911, pp. 41–42.

Composition of graphic granites calculated into their norm components.

No.	Locality.	Feldspar content.			Free quartz.	Reference.		
		Potash feldspar.	Soda feldspar.	Lime feldspar.		Designation of sample.	Bulletin.	Page.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*			
1	Hitteren, Norway	51.2	14.3	0.5	34.0	Bygden No. 8	U. S. Geol. Survey Bull. 445	41
2	Skarpo	58.2	10.6	1.7	29.5	Bygden No. 7		
3	Cathance, Me.	51.1	16.9		27.6	Graphic granite B	This bulletin	
4	Georgetown, Me.	50.6	19.0		27.4	Graphic granite C		
5	Reade	48.1	20.5	4.1	27.3	Vogt No. 4	U. S. Geol. Survey Bull. 445	41
6	Topsham, Me.	54.4	18.5		27.1	No. 1	do	124
7	do	55.2	18.5		26.3	No. 2		
8	do	53.4	18.2		25.8	Graphic granite A	This bulletin	
9	Voie, Arendal, Norway.	55.1	17.9	1.6	25.3	Vogt No. 1	U. S. Geol. Survey Bull. 445	41
10	Hitteren, Norway	52.0	21.5	1.8	24.7	Vogt Nos. 2 and 3		
11	Arendal, Norway	48.9	25.8	1.8	23.5	Vogt No. 5		
12	Bedford, N. Y.	47.4	28.4	1.0	23.2	No. 3	do	124
13	Elfkarleo	59.2	19.4	.6	20.8	Bygden No. 6	do	41
14	Portland, Conn.	51.2	29.2	.2	17.4	No. 4	do	124
15	Rodo	6.0	47.8	2.8	39.0	Bygden No. 9	do	41
16	Ytterby	2.7	46.3	13.1	37.9	Bygden No. 11		
17	Evje	8.5	51.9	7.9	31.7	Vogt No. 6		
18	Beef Island	3.8	55.5	22.4	18.3	Bygden No. 12		

The table discloses the fact that the ratio of potash feldspar to soda feldspar in graphic granite is generally greater than 2 : 1 and often reaches 3 : 1. In those samples in which soda feldspar is the prevailing type of feldspar the potash feldspar is present in very small amount only. The graphic granites 15, 16, 17, and 18 belong to a class entirely distinct from the others. A fact worthy of note is the small variation in norm content of potash feldspar in Nos. 1 to 14, inclusive. With the exception of Nos. 2 and 13, the potash feldspar content is between 47.4 per cent and 55.2 per cent of the graphic granite, whereas the soda feldspar in the same series varies from 10.6 per cent to 29.2 per cent. In the first 14 samples—that is, the graphic granites high in potash feldspar—only two contain more than 27.6 per cent free quartz and only two contain less than 23.2 per cent. Thus 70 per cent of the graphic granites studied contain 23.2 to 27.6 per cent of free quartz, a variation of 4.4 per cent.

PROSPECTING AND SAMPLING.

Too much emphasis can not be placed upon the importance of thoroughness in prospecting for feldspar and in sampling the deposit when located. Practically all the failures in feldspar quarrying are due to improper prospecting and sampling, which has led to an overestimation of the extent of the deposit and of the quality of material obtainable. In many instances the analysis of hand specimens taken in the course of ordinary prospecting have been made the basis of large investment and expenditures where the material of the grade sampled is so limited as to hardly justify a passing glance.

In prospecting for feldspar the geology and topography of the district must be carefully considered. If the country rock is more easily eroded than granite or pegmatite the dikes or sills are exposed above the surrounding country. If the country rock is more resistant to erosion than granite or pegmatite, the existence of the dikes or sills is indicated by depressions. Throughout the New England and North Appalachian States the former case prevails and in many places pegmatite rich in feldspar is exposed along the ridges or along the steep slope of the hills.

When such an exposure is found or a deposit of pegmatite is in any way discovered, the prospector should first ascertain the general nature of the walling rocks. From a hasty survey the existence of folding or faulting can be determined and also the deposit classified as dike or sill. An exposure may be either across the dike or along its strike and what may seem to be the face of a broad lens may be in reality only a thin sheet. With the formation identified as dike or sill the prospector should proceed to determine the strike and dip as well as the general dimensions of the deposit. To do this the overburden should be removed from the exposure until the full width of the deposit is bare. With the data thus obtained the apparent strike should be projected 50 feet and the deposit uncovered at that point. Sometimes this projected continuation of the dike will prove erroneous, hence it is advisable where the overburden is heavy to locate the dike first by drilling. Prospecting should be continued at intervals of not more than 50 feet in both directions from the original exposure, and if the deposit seems to vary greatly in dimensions the intervals should be reduced to 25 feet.

The location of the dike by drilling is only of value as a labor saver in determining where the cuts shall be made. The reason for this is obvious. The drill sample can merely indicate that the formation is of a granitic nature and shows little as regards size of grain or the extent to which impurities exist.

After locating the limits of the deposit therefore open cuts or at least a pit should be made in order to expose a reasonable area of the surface. These exposures should not be farther apart than 50 feet. The cutting of a trench across the entire deposit as compared with sinking a pit through the overburden has been proven by experience to be little if any more expensive, as the trenching can be done with plow and scraper, whereas in digging a pit most of the work is necessarily hand labor.

Which surface is exposed by this method depends on the nature of the deposit, if it is a dike the surface exposed represents the cross-sectional face of the deposit; if a sill the surface exposed is one of the walls and does not in any way represent an average of the deposit. The mode of procedure therefore depends upon the nature of the deposit.

SAMPLING A DIKE.

To sample a dike from the trenches cut, the most satisfactory method is as follows: Lay off the dike from wall to wall in 5-foot centers, beginning at a point 1 foot from the foot wall and placing the last center not more than 3 feet from the hanging wall. At each of these centers drill a row of three holes, 3 feet deep and 2 feet apart, on a 45° slope toward the hanging wall, the rows being at right angles to the trench wall. Charge each hole with one stick of "60 per cent" or one and one-half sticks of "40 per cent" dynamite, and tamp well with soft clay after attaching the detonator or exploder wire. Fire by whatever method is most convenient, but fire the rows in regular order, beginning with the one next the hanging wall. Much better results will be obtained if all the holes of a row are fired simultaneously. Each row should be carefully sampled and all loose débris cleaned away before the next round of shots is fired. As soon as the shots are fired, the loosened material should be removed and broken into pieces of approximately 3 inches diameter or less.

This material should include all that is loosened by the shot, but judgment should be used in handling it—for instance, a block of mica which was imbedded in the mass, but was entirely independent of the remaining material, should not be crushed and mixed with the other material loosened by the shots.

A careful record of the surfaces exposed should be made and especial emphasis should be placed on the gradation from the surface inward as regards size of grain and presence of associated minerals.

The material loosened by a row of shots should all be piled on a sampling cloth or wooden platform and thoroughly mixed, quartered, and two opposite quarters discarded. After mixing the remaining material thoroughly, it should be quartered, and two opposite quarters discarded. What remains on the cloth should be broken into pieces not to exceed 2 inches maximum diameter and the whole thoroughly mixed together. By repeated quartering this mass should be reduced to a sample of about 5 pounds.

In quartering especial care should be taken that the quarters discarded are entirely removed, because if some fine material is left on the sampling cloth each time, as is sometimes done by careless samplers, the resultant 5 pounds will contain an excessive amount of this fine material, which may have a different composition from the coarser material.

If the faces exposed by the shots indicate that the dike material improves rapidly with depth it may be advisable not to sample the rock next the surface, but to obtain the sample from the bottom of the holes. This can sometimes be done by striking with a heavy sledge the faces exposed in the bottom of the blast hole. If this is not effective a single hole may be bored in the bottom of the blast hole. This drill hole should slope 45° toward the foot wall, thus cutting under the face exposed by the first shot with the minimum depth of drill hole. A single hole 2 feet deep charged with one stick of "60 per cent" dynamite will generally move enough pegmatite to afford a good sample and this sample should be all removed and carefully sampled as explained above. After all the centers in all the trenches have been sampled in this manner, the depth of the dike is still to be determined. As this involves considerable expense for sinking shafts or cutting a tunnel, it may be advisable to first make or have made fire tests of the samples already taken. If the results of the tests prove satisfactory, the prospector is now ready to select a site for the test shafts or tunnel. The selection of this location will depend more or less on the topography of the country. If shafts are to be used at least two will be necessary and they should be at least 50 feet apart along the strike of the dike. One may be sunk at the natural place to open the dike, and the other should preferably be on higher ground. The shafts should be sunk not less than 25 feet into the dike material or until the grade of the product is proven too low for commercial use. The most convenient small shaft is a 3 by 6 foot rectangular shaft, with the larger dimension across the dike. In sinking such a shaft, frequent and detailed record should be made of the appearance of the rock, and at intervals not exceeding 5 feet a 50-pound sample should be taken, and each of these samples crushed and quartered to a 5-pound sample after the manner described above. If more than one band of the dike is exposed in the shaft, each band should be sampled separately.

TESTING FELDSPAR.

If a feldspar as marketed was the powder of a pure mineral, the chemical analysis would doubtless afford a reliable means of checking the various shipments and thus insure uniform results from its use. As the feldspar of commerce necessarily contains other minerals which are associated with it and as the term "feldspar" is used to cover a broad range of chemical composition, the safest course for the user who desires uniformity of results is to determine the chemical composition and also the physical properties of the feldspar. For the methods of chemical analysis of feldspars, the reader is referred to United States Geological Survey Bulletin 422.[a] The most important physical properties of feldspars are as follows: Temperature of deformation or fusion; rate of deformation; color when deformed and after complete fusion; shrinkage which its introduction imparts to a standard porcelain body.

TEMPERATURE OF FUSION.

Feldspars fuse at widely varying temperatures, owing to their great variation in chemical composition. When to this cause of variation is added that of an uncertain proportion of mineral other than feldspar, only a very general prediction can be made as to the physical and pyrometric properties of the mixture.

Fusion is a progressive process and covers the entire pyrophysical change from the solid to the fluid state. The only means of measuring the degree to which the process has attained is to determine the change in viscosity of the mass.

Measurement of the viscosity of fusion by means of physical apparatus is a difficult operation, and the apparatus at present available is not suitable for the use of any but highly trained experimentors. Fortunately for the practical man, as well as for the more highly trained investigator, there is a simple and accurate method of measuring viscosity change in the early stages of fusion which affords a reliable means of expressing the relative temperature and rate of fusion.

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[a] Hillebrand, W. F., The analysis of silicate and carbonate rocks: U. S. Geol. Survey Bull. 422, 1910, 239 pp.

TESTING WITH STANDARD CONES.

The method referred to is standardization against standard pyrometric cones of known deformation temperature and rate of deformation. Deformation may be defined as the first visual evidence of fusion and indicates the reduction of viscosity to the point where the mass is no longer able to support its own weight. The rate of deformation evidences only the rate of fusion in its early stages, but by the method employed the possibility of error is reduced to the minimum.

The standard pyrometric cones are made from a series of mixtures of carefully tested and standardized materials similar to those employed in porcelain manufacture. They were first produced by Dr. Herman Seger under the patronage of the German Government. The temperature at which the cone deforms is regulated by its composition. Seger made a series of standard cones to fuse at intervals of 20° C. between 1,150° C. and 1,650° C., and numbered them 1 to 26. Later a series of standard cones for temperatures from 950° C. to 1,130° C. were devised by E. Cramer, an associate of Seger. The members of this series also fuse at temperature intervals of 20° C., and are numbered 010 to 01. A series of standard cones were later produced for temperature above 1,650° C., and these are known as Nos. 27 to 42, the latter being the fusing point of pure alumina. The temperature at which these pyrometric cones fuse is affected to a greater or less degree by the heat treatment which they receive, but with firing conditions constant they are reliable to within a few degrees.

The standard cones of the Seger series, which are the only ones in which the feldspar investigator is interested, are as follows:

Seger series of standard pyrometric cones.

Cone No.	Deformation temperature, °C.	Cone No.	Deformation temperature, °C.
1	1,150	12	1,370
2	1,170	13	1,390
3	1,190	14	1,410
4	1,210	15	1,430
5	1,230	16	1,450
6	1,250	17	1,470
7	1,270	18	1,490
8	1,290	19	1,510
9	1,310	20	1,530
10	1,330	26	1,650
11	1,350		

Cones Nos. 21 to 25, inclusive, have proved so erratic in their behavior under commercial firing conditions that their manufacture and use have been abandoned both in Europe and America. The temperatures between 1,550 and 1,630° C. have proved impractical, however, for ceramic firing and in commercial practice there is no demand for cones deforming between these temperatures.

The process of manufacture of these standard pyrometric cones is as follows: The various ingredients are weighed in proper proportion and thoroughly ground to a homogeneous mixture. This mixture is made plastic by additions of a solution of dextrine and pressed in molds. After molding, the cones are baked at a low temperature to make them strong enough to permit handling. The shape and dimensions of the dried standard cone are shown in figure 14.

The material to be tested is ground to an impalpable powder and by a small admixture of dextrine, cornstarch, or similar solution is rendered sufficiently plastic to permit of its being pressed into cones of the same shape and dimensions as the standard cones. After drying these cones are ready for test.

METHOD OF TESTING.

A slab of fire clay is prepared and into this the cones to be tested are embedded about one-sixth their height. The cones should be spaced as closely as possible and not interfere with one another in deforming. Standard pyrometric cones should be placed upon the same slab or on separate slabs, and in as close proximity to the cones being tested as safety of operation will permit. The slab and cones, after being carefully dried, are so placed in an inclosed muffle furnace that no direct flame can strike the cones and the temperature is gradually raised until the desired deformation occurs (Pl. I, *C*).

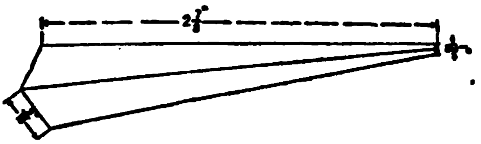

FIGURE 14.—Standard cone for deformation test.

A close watch must be kept over the process, as there are two stages to be observed—the shrinkage stage and the deformation stage. The first or shrinkage stage is well in advance of the deformation stage in some cases, and a considerable rise in temperature may elapse before any evidence of deformation is noticeable. Specimens that were removed from the furnace after reaching only the shrinkage stage have been found to be dense and slightly translucent, indicating that the process of fusion had begun in the individual particles but that nothing more than a cementing together of the particles had occurred. The shrinkage stage is characteristic of the standard pyrometric cones and hence these can not be used as standards by which the shrinkage may be gaged. However, as most standard cones do not begin to shrink perceptibly until heated within about 40° C. of the temperature at which deformation begins, it is practical to use as a standard for gaging the shrinkage one of the standard pyrometric cones No. 12 to No. 14, which will certainly not begin to shrink until any feldspars that may be used in ceramic manufacture are well advanced in the process of deformation.

In placing the cones on the slab of fire clay it is highly desirable to slant them all slightly and uniformly in the direction in which it is desired that they should deform.

The process of deformation begins when the first evidence of bending is discerned, and is completed when the point of the cone touches the surface of the slab on a level with the base. Stages of deformation beyond the latter point are not easily determined owing to uncertain effect of the supporting action of the plate on two points of the cone. The first evidence of deformation of the feldspar should be carefully recorded with data regarding the degree of deformation of the standard pyrometric cones against which it is being standardized. As its deformation progresses frequent records should be made both of the feldspar cone and the standard cones. This data is valuable in direct proportion as the number of careful readings, since these indicate the rate of deformation.

Time is a factor which must be carefully considered in expressing the temperature of deformation of any feldspar or standard cone. A careful record should be made of the time which elapses between the application of heat to the feldspar and standard cones and the beginning and termination of the deformation process. Also a record should be made of the rate of increase of temperature in the inclosure containing the cones. This data may be obtained by providing a series of standard pyrometric cones which deform at stated intervals from red heat to the critical temperature of the feldspar being tested.

USE OF PYROMETERS.

A more satisfactory means of procuring this data is by employment of one of the numerous pyrometers designed for temperature determination, many of which are equipped with an automatic recording device by which the rise in temperature is plotted on a sheet suitably prepared for such record. Pyrometers other than pyrometric cones may be classified as follows: (1) Thermoelectric pyrometers, (2) heat-radiation pyrometers, and (3) optical pyrometers. A brief description of these thermometers which has been given in Bulletin 53[a] is included here:

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[a] Watts, A. S., Mining and treatment of feldspar and kaolin in the southern Appalachian region: Bull. 53, Bureau of Mines, 1913, pp. 23-24.

THERMOELECTRIC PYROMETER.

The thermoelectric pyrometer is an instrument for ascertaining the temperature in an oven or kiln. It consists of a thermoelectric couple, made by fusing a platinum wire and a wire composed of 90 per cent platinum and 10 per cent rhodium, which is exposed to the temperature. The difference in temperature between the hot and the cold junctions of these two wires is proportional to the electric current generated, and this is recorded on a galvanometer. The deflection of the galvanometer varies with the current generated, and the dial of the galvanometer, being scaled in centigrade degrees, permits the operator to read directly the temperature of the furnace. Such an instrument is reliable to 3° C. under ideal laboratory conditions, and is reliable within 5 to 10 degrees under factory conditions. The electric pyrometer is highly satisfactory for use in testing feldspars, but as the deformation of a feldspar is a pyrochemical process, in which heat and time are factors, the time consumed in heating the sample to the deformation temperature should be considered in expressing the deformation temperature of any feldspar or feldspar mixture.

The thermoelectric pyrometer deteriorates rapidly at temperatures above 1,500° C., hence for testing kaolins and quartzes Seger cones or some form of heat radiation or optical pyrometer must be used.

HEAT-RADIATION PYROMETER.

In the heat-radiation pyrometer the heat radiated from an incandescent body, in the furnace or kiln, is focused on a thermocouple and the electromotive force generated is indicated by the deflection of an attached galvanometer, which is read on a dial scaled in centigrade degrees. The precautions that the operator must consider in using such a pyrometer are to have the incandescent object focused sharply upon the thermojunction and to have the image so focused of greater size than the junction.

Such a pyrometer is reliable only within 10° C. under the most favorable conditions; hence its use is little, if any, more satisfactory for temperature measurements than are the pyrometric cones.

OPTICAL PYROMETER.

The optical pyrometer of La Chatelier consists of a telescope that carries a small comparison lamp attached laterally. The image of the flame of this lamp is projected on a mirror at 45 degrees placed at the principal focus of the telescope. The images of the object viewed and of the comparison flame are side by side and are brought to equal intensity by suitable adjustment of the instrument. Under the most favorable conditions this instrument is subject to any error of vision of the operator and for high temperatures should hardly be expected to give results more accurate than 10° C.

As the deformation of feldspars may in some cases be completed within a temperature range of 5° to 8° C., the use of thermocouples or optical pyrometers does not furnish a graphic comparison. Seger cones, placed side by side with the sample to be tested, is by far the most satisfactory method of comparison, although it is always advisable to use a thermocouple or optical pyrometer to check the temperature of the deformation.

The cone of material of which the deformation point is to be determined is placed on a fire-clay slab to which it is made fast by means of a fusible slip or by packing clay about the base. If clay is packed about the base care must be used that the cone be set not more than one-fourth inch in the clay lest the deformation be retarded. If the deformation temperature is to be determined by means of cones, these should be placed about the cone to be tested and as near as possible without danger of contact when deformation begins. If the cones are not set exactly vertical, care must be taken that the same slant be given to all, otherwise the results will not be comparable.

As the rate of fusion is an important factor, the cones should be closely watched and the time at which each standard cone is exposed to the heat should be recorded, the time at which it begins to deform, and the time at which its point reaches the level of its base, the cone forming a semicircle. A similar record for the cone of the material being tested enables one to determine, by referring to the standard-cone record, the temperature of the beginning of deformation and also the temperature at which its point reaches the level of its base. The range of temperature between these two stages of deformation is very important as indicating the range of temperature within which the material under test will be valuable as a flux in pottery manufacture.

PROPERTIES OF FELDSPAR IN PORCELAIN MIXTURES.

The following description of methods of testing the pyrometric properties of feldspar is taken from Bulletin 53:[a]

TESTING BY MEANS OF STANDARD TRIALS.

The rôle of feldspar in the porcelain mixture is that of a cementing material or solvent, its activity depending on the temperature attained in the firing process. If the temperature only softens the feldspar the latter can do nothing more than bond the quartz and kaolin with which it is intimately mixed. If the feldspar is heated until it becomes fluid, it can take into solution part of the quartz and kaolin, and thus form a more or less homogeneous mass. Impurities in the feldspar may not seem very injurious in their action when the feldspar is tested alone, but may materially affect the speed of reaction and other properties of the feldspar when used in porcelain mixtures.

The action of a feldspar in porcelain mixtures is the only safe and proper basis for judging its industrial value. Experience has proved that it is not essential that the proportions of a porcelain mixture for testing be industrially correct but rather that those proportions be selected which will cause the ingredients to display most pronouncedly any faults that they possess. Thus an excess of feldspar will increase the tendency to warp and also to produce bad colors. For practical test the following proportions have been found most satisfactory: Feldspar, 20 per cent; kaolin, 50 per cent; and quartz, 30 per cent; mixed with 50 grams of water.

A standard for each of these materials should be selected from the best material on the market and should be thoroughly tested as to its physical and chemical properties. From these standard materials a standard trial mixture or blank should be prepared in the proportions given above and this standard trial should be tested in exactly the same manner as the mixture containing the material under test.

METHOD OF PREPARING TRIALS.

The standard plastic trials are produced by mixing the materials in the proportions given above. Especial attention should be given to the thorough mixing of these materials into a homogenous mass, as otherwise the trial mixture lacks uniformity and is unreliable. After being thoroughly mixed and kneaded the material is formed, by jiggering or by pressing into molds in such a manner that a product of varying thickness will be obtained.

For this trial a wedge-shaped rectangular block, which may be any desired length, is most satisfactory. If one edge is sharp and the other three-fourths of an inch thick the trial can be used for translucency and color tests; and by impressing the face with a metal die a record of linear shrinkage may also be obtained. Care should be observed that this mark for shrinkage or identification does not interfere with the translucency test.

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[a] Watts, A. S., Mining and treatment of feldspar and kaolin in the southern Appalachian region, Bull. 53, 1913, pp. 32-36.

For testing the feldspar a mixture should be prepared in every way similar to the standard trial or blank, except that the feldspar to be tested should be substituted for the standard feldspar. In the molding of trials the process employed in making the standard trials must be carefully duplicated if comparable data are expected. All test pieces should be conspicuously marked to insure identification.

As soon as trials are removed from the molds they should be placed where they may dry without warping, and when thoroughly dry the drying shrinkage may be determined by measuring with calipers the impression made by the die.

FIRING.

In firing the trials the temperature attained should be that to which the feldspar will probably be subjected in commercial work. For convenience this temperature may be safely assumed to be about that at which, in the deformation of the trial, the point reaches the level of the base, as described under deformation-point determination.

VITRIFICATION RANGE.

Vitrification range is that range of temperature within which the feldspar being tested produces a vitreous body that does not warp. The vitrification range of feldspar is determined by means of a bar one-half by one-half by 6 inches composed of a mixture similar to the standard porcelain mixture, except that the standard feldspar is replaced by the feldspar being tested.

This bar, after thorough drying, is so placed in the kiln that it is supported 1 inch from each end, leaving the 4 inches in the middle unsupported. The temperature at which warping begins marks the highest temperature that is practical for this feldspar in this proportion and is considered the maximum temperature of the vitrification range. The minimum temperature of the vitrification range is determined by firing to various temperatures the trials containing the feldspar being tested; they are then carefully weighed dry, and after standing for 24 hours in pure water are removed, carefully dried on the surface only, and reweighed. The increase in weight indicates the absorbed water content. The minimum temperature which renders the trial nonabsorbent is the minimum temperature of the vitrification range.

COLOR.

In the absence of a standard system of measuring color, the method employed is by comparison, using the standard porcelain mixture made and fired under comparable conditions as a standard.

TRANSLUCENCY.

Translucency is determined by placing the wedge-shaped translucency trials over a 1-inch hole in a box that contains a 16-candlepower electric lamp of constant brilliancy. The maximum thickness of the trial, expressed in centimeters, through which a No. 20 wire can be detected on the face of the trial next the lamp with the lamp 3 inches distant, is taken as a measure of translucency.[a]

SHRINKAGE.

Shrinkage is determined by measuring the length of the die impression made in the wedge used in the translucency test. The total shrinkage is the difference between the original length and the length after firing.

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[a] Weelans, Charles, and Ashley, H. E., Report of the committee on the classification of white ware: Trans. Am. Cer. Soc., vol. 13, 1911, pp. 104-105.

TEST UNDER GLAZE.

An important property of all feldspars is their effect on the color of the body, both unglazed and glazed. Many porcelain bodies are of faultless color when unglazed, but when covered with a clear glaze the defects of the ingredients show, and the body as viewed through the glaze is so badly off-color that the commercial value of the ware is greatly reduced. Tests under glaze are therefore of much importance, and as the glazes used are of two classes—namely, raw-lead and fritted—it is advisable whenever possible to apply to the fired trials a thin coat of glaze. For convenience it is desirable to place a small quantity of each glaze on the same trial or test piece, in order that the effects of the different glazes may be most clearly compared. A small part of the trial should be left unglazed, in order that the effect that glazing has on the color may be determined by comparison.

For tests of materials in porcelain mixtures under glazes, those glazes should be chosen that are most likely to be used with the materials in commercial work.

For this test the following glazes have been found satisfactory and are recommenced for use at temperatures between cone 02 and cone 2—that is, approximately, 1,110° to 1,190° C:

Raw-lead glaze.

Molecular formula.

$$\left.\begin{array}{l}0.6\ PbO\\0.1\ K_2O\\0.15\ CaO\\0.15\ ZnO\end{array}\right\}0.15\ Al_2O.\quad 1.5\ SiO_2,$$

Composition of batch by weight.

	Per cent.
White lead	51.81
Potash feldspar	18.60
Whiting	5.02
Zinc oxide	4.20
Kaolin	4.32
Flint	16.05
	100.00

This material is ground with water enough to produce a thin paste and is applied as a coat of uniform thickness to all the test pieces to be compared.

Fritted glaze.

Molecular formula.

$$\left.\begin{array}{l}0.13\ K_2O\\0.25\ Na_2O\\0.25\ ZnO\\0.25\ CaO\\0.12\ PbO\end{array}\right\}0.22\ Al_2O_3\left\{\begin{array}{l}1.25\ SiO_2\\0.50\ B_2O_3\end{array}\right.$$

Composition of batch by weight.

	Per cent.
Melted frit	37.02
Potash feldspar	31.02
White lead	13.30
Zinc oxide	8.70
Kaolin	9.96
	100.00

Frit.

Molecular formula.

$$\left.\begin{matrix}0.5\ Na_2O\\0.5\ CaO\end{matrix}\right\}\ \left\{\begin{matrix}0.58\ SiO_2\\1.00\ B_2O_3\end{matrix}\right.$$

[Composition of batch by weight, raw.]

	Per cent.
Borax	69.25
Whiting	18.13
Flint	12.62
	100.00

This frit is melted to a glass, cooled, and ground to pass a 150-mesh sieve. The ground melted frit is added to the glaze in the proportion given above, and the mixture is thoroughly ground before being applied to the trials. The fritted glaze is generally applied in a thinner coat than that necessary for the raw-lead glaze.

BLANK OR STANDARD TRIAL FOR FELDSPAR.

The blank or standard trial for feldspar consists of the standard porcelain mixture, and contains the standard feldspar, kaolin, and quartz in the proportions specified.

The chemical composition of the standard feldspar is as follows:

Composition of standard feldspar.

	Per cent.
H_2O	0.35
SiO_2	71.75
Al_2O_3	16.70
Fe_2O_3	.14
TiO_2	.03
CaO	.25
MgO	.....
K_2O	8.59
Na_2O	2.99
	100.80

The standard feldspar has a deformation temperature range of 1,300° to 1,320° C. When fused it becomes a milky glass without any yellow tint.

In the standard porcelain mixture this feldspar produces a vitreous mass at 1,310° C. and at 1,350° C. shows no indication of warping. The color is a vitreous white without any distinguishable cream or blue tint. At 1,350° C. the feldspar produces a translucency of 0.65, and a total shrinkage of 15.6 per cent, 3 per cent of which is drying shrinkage and 12.6 per cent firing shrinkage.

QUARRYING AND QUARRYING METHODS.

The methods of quarrying dike materials vary greatly in different localities, owing to the wide difference in structure of different deposits and the varying amount of worthless material which must be handled.

Most pegmatite deposits outcrop along a part of their strike, and the common error of opening a quarry where the dike material is most easily and cheaply accessible, without due consideration for future operations, has caused many a venture to fail which with a little more care might have been a success.

Dikes rarely have vertical walls, and if a dike is opened from the foot-wall side the removal of the material below the hanging wall may necessitate the handling of a large amount of hanging-wall refuse. In many cases the deposit may be as conveniently opened on the hanging wall, and the foot-wall material need not be disturbed, so that the expense of handling this material may be avoided.

Careful planning of the method of attack is especially necessary in dealing with the isolated lenses of foreign or wall material which are to be found in all dikes and sills, the removal of which often absorbs all the profit from the marketable material obtained.

The dikes often contain impure bands throughout their entire extent. If these impure parts are along the walls, the quarrying may be so planned that only at the entrance and in parts of the hanging wall need the impure material be disturbed. If the capping of the dike is worthless because of impurity, it may be removed first and the great annoyance of handling this refuse on the quarry floor with the marketable material be avoided.

Where there is a definite impure band in the heart of the dike it is often advisable to remove the dike material only on one side the impure band and leave the other part until the band can be separately removed without serious difficulty.

The reason for working a quarry in such an irregular manner is evident if the expense of sorting the quarried products by hand is thereby avoided. Where biotite or tourmaline is scattered throughout the deposit and hand sorting of all marketed material is necessary, it would hardly be advisable to quarry the two sides and the impure band separately.

THE OPENING OF A QUARRY.

Careful consideration should be given to the opening of a quarry in order that the material may be handled as economically as possible. This consideration may involve opening the deposit at a point widely removed from the easiest point of attack.

Where the strike of the deposit follows the face of a hill and the deposit has been proved over a considerable area, the opening cut should be made across the entire width of the dike. From this crosscut entrance the deposit may be worked across the entire face. Only by this method can the production be maintained uniform for any great period of time.

If the deposit strikes across the hill it is necessary to confine operations to one face only, except in extraordinary cases where both ends of the deposit are so situated that quarrying may be carried on equally well from either end. In most cases one face presents greater advantages. If the hillside has a gradual slope, it is often practical to work the deposit on an upper level until a sufficient area is provided for convenient operation and then at a considerably lower level make a new opening, and thus increase the production over that possible from the single opening.

The quarrying of dike materials may be conveniently divided into two classes—(*a*) quarrying the part above water level and (*b*) quarrying the part below water level.

Such a classification is necessary, owing to the many special problems and considerations connected with quarrying below water level; also the added cost of getting out the rock. Many quarries which belong in class (*a*) are forced into class (*b*) because of mistakes made in opening the property or of improper methods of quarrying.

Where the dike is so located as to fall into class (*a*) the operation of quarrying consists in (1) removing the overburden, (2) quarrying the dike material by benches, (3) sorting the loosened material, (4) removal of the marketable and refuse material from the quarry, (5) handling of the marketable material between quarry and mill.

REMOVING THE OVERBURDEN.

The removal of overburden from a feldspar deposit is a subject which deserves especial consideration because careless stripping has caused more trouble than almost any other feature of quarrying. The operator is inclined to think that the overburden, being soil, will not contaminate the rock feldspar and, hence, may be allowed to wash down the face of the quarry or lie in heaps on the half-loosened feldspar masses about to be crushed for the mill.

The most injurious impurity with which the manufacturer of pure white pottery material has to deal is oxide of iron. The ordinary surface soil contains considerable quantities of oxide of iron in an extremely fine state. When this soil washes or caves down onto the masses of feldspar, this iron is infiltrated into the crevices and also coats the exterior of the rock. Subsequent knocking about prior to pulverizing does not remove the iron and it is pulverized with the feldspar, producing a product apparently white, but which develops numberless gray and brown specks on firing. Increased care and thoroughness in the removal of overburden is especially commended to the consideration of the quarry operators.

The overburden should be removed for a width of 20 feet from the quarry face. If the depth of the overburden is great, it should be stripped back far enough to insure against any slides falling into the quarry. At a short distance from the quarry face an ample drainage ditch should be cut to divert surface water from the quarry.

The overburden can generally be removed by plow and scraper when removed well in advance of the quarrying, and this method is much more economical than removal by hand, as is necessary when the overburden is allowed to remain until the quarried face is within a few feet of it.

QUARRYING THE DIKE MATERIAL.

In quarrying the dike material the depth and width of the benches will depend on the texture of the pegmatite; in most cases the best depth for drill holes is found to be 6 to 10 feet. The holes should be not more than 3 feet apart. The width of the bench should never be less than 4 feet, and 6 feet is a more economical and convenient width for drilling. It can be readily understood that, as the drilling of the holes is the most expensive item of the quarrying, the greatest possible amount of rock must be moved per hole drilled, provided the bowlders loosened shall not require subsequent drilling to bring them to a convenient size for handling.

The entire length of the bench should be drilled and loaded and the complete string of holes shot at one time. This is naturally more effective than where each hole is fired separately.

The diameter of hole is generally 2 inches, and the explosive used varies from "40 per cent" to "60 per cent" dynamite. In one instance "30 per cent" dynamite is reported as being used. For a 10-foot hole on a 6-foot bench, where a string of holes 3 feet apart are drilled, a charge of six sticks of "40 per cent" or four sticks of "60 per cent" dynamite is the normal charge per hole. The detonators caps used are Nos. 4, 5, and 6, the No. 6, however, being now almost universally used. Electric exploders are now almost universally used in feldspar quarries.

The breaking of the feldspar into coarse lumps instead of fine material has come to be general quarry practice except where the amount of impurity present makes close inspection necessary. The coarse material can be handled much more economically than fine material and can be crushed with little added expense. When the lumps fail to break readily, a small adobe (mud-capped) or a short-hole shot will quickly and economically reduce them to a convenient size for handling.

When a bench has been shot down and the coarse lumps reduced by sledge or explosive to a convenient size for handling, drilling may begin on the next bench while the fresh material is being removed from the quarry.

A much neglected but very important point in the successful operation of a quarry is the maintenance of a smooth and clean quarry floor. All the expense of maintaining a good floor is repaid by the economy of handling the material in removing it from the quarry.

SORTING THE MATERIAL.

The operation of sorting the feldspar and removing, by cobbing, any impure parts which are found adhering to otherwise pure feldspar is a task of varying importance in different quarries. In some instances the entire quarried product is removed from the quarry and sorted in sheds or on convenient piles and the refuse returned to the dump in a worked-out part of the quarry.

In most cases the extra handling of this impure material would add much to the cost of production, and the common practice is to load only the reasonably clean feldspar into the conveyance for removal from the quarry, the more impure material being conveyed directly from the bench face to the dump.

The moving of the broken rock from bench faces to bin or dump is a considerable problem. Within the Maine and Connecticut feldspar-producing district several quarries are using light hopper cars of the side-dump type that run on a track and are drawn by horses. The other quarries use the ordinary dump cart drawn by horse or handle all material in wheelbarrows.

None of the feldspar quarries of Maine and Connecticut has railroad connection to the quarry, and only one has harbor facilities without a considerable wagon haul. The expense of loading and unloading and the cost of hauling add considerably to the cost of the feldspar at the mill.

If the roadway from the quarry to the bins and dump can be maintained at a slight incline, so that the material can be handled by gravity, a considerable saving can be effected; and if in addition to this a dump-car system is employed, the cost of hauling and handling can be greatly reduced. No universal system can be offered for such operation, however, as no two feldspar properties have sufficiently similar surroundings to permit of a standard system.

QUARRYING FELDSPAR BELOW WATER LEVEL.

Where the deposit is below the level of a neighboring stream or body of water, or so far from the slope of the hill as to render a horizontal entrance impracticable, the dike must be opened from above. Fortunately such deposits are exceedingly rare, and as yet few such operations have been attempted. Most operations which fall in this class have been opened above water level, and when lower levels were reached pumps have been resorted to instead of cutting outlets at lower levels. When the working level reaches a point 30 feet below the outlet and the suction pump can no longer lift the water, under even the most favorable conditions, more expensive pumps are installed or a relay system of suction pumps is used.

The greatest expense of quarrying below water level consists in lifting the quarried rock to the surface. The great area being worked practically necessitates conveying the material to a central point, from which it is elevated. This extra handling adds to the expense. The actual cost of removing water or of elevating material does not render this method of quarrying excessively expensive, provided it is conducted in an economical manner and the deposit contains a sufficient quantity of marketable material to justify the installation of the necessary equipment.

Many of the feldspar deposits of Maine and Connecticut are isolated lenses and contain only a few hundred tons of merchantable feldspar. These are worked as shallow pits and the water which naturally drains into them is removed by siphon. When the feldspar has been removed the operator abandons the pit, which fills with water and adds another to the hundreds of small lakes which dot the country.

DRAINING THE QUARRY.

Although the amount of water to be removed from the average feldspar quarry is almost insignificant compared with that removed from most metal mines, the removal of water has been a source of great annoyance and excessive expense in many quarries. The custom at many of the smaller quarries of bailing the pit and hoisting the water with the apparatus used for hoisting the feldspar is followed in some of the larger ones, but the amount of manual labor required prohibits this method, except in emergency cases or where the quarry has been idle and, having filled with water, must be unwatered before quarrying can be resumed.

METHODS OF DRAINAGE.

The method to be selected in dewatering a mine is a matter which has received considerable attention from mining engineers, and a brief survey of the methods for removing water will be of interest.

SIPHON.

The siphon is the simplest and cheapest system of raising water if conditions are such as will permit of its use. The pipe is ordinary service pipe with tight fittings. At the outlet end is a valve which is the full size of the pipe, and above this valve is an attachment for a substantial hand pump or small power pump for starting the siphon. To avoid the labor of starting the siphon at frequent intervals it is necessary to observe when the water has been almost entirely removed from the quarry and shut off the valve at the outlet end of the pipe, leaving the siphon full of water. For convenience it is also wise to have a well or sump in the quarry and drain all the workings into it. A siphon is not possible except where the outlet end of the pipe can be well below the intake.

PUMPS.

STEAM PUMP.

The steam suction pump is the commonest form of pump used in connection with quarrying. The custom of placing the pump outside the quarry in many instances reduces its efficiency, because the weight of the column of water almost totally overcomes the suction. If the pump is placed on the quarry floor and the steam pipe is properly covered to prevent radiation, its efficiency should be greatly increased, because it then acts as a force pump. Where the floor of the quarry is liable to be flooded it may be advisable to place the pump on a ledge above the floor, but as low in the quarry as practicable.

CORNISH PUMP.

The Cornish rod pump is considered the cheapest means of lifting water where the quantity is sufficient to justify such an installation. This system of pumping can be worked at almost any depth, and, although its use is at present confined chiefly to deep mines, it would doubtless prove satisfactory where the quantity of water to be lifted is large.

COMPRESSED-AIR PUMPS.

Compressed-air pumps have little to recommend them for use in quarries unless the drills are operated by this power. If the amount of water does not necessitate continuous pumping, it is often practicable to drive a pump by this power when the drills are not running.

ELECTRICALLY DRIVEN PUMPS.

A pump driven by an electric motor has the advantage of being easily moved, and where hoists, trams, etc., are motor driven, the employment of this type of pump for hoisting water is thoroughly practical.

CAUSE OF PUMP TROUBLE, AND REMEDY.

The cause of practically all the trouble with pumps about quarries is the clogging of the valve in the suction end of the pump by particles of refuse. The remedy for this is a strainer attached to the intake pipe. This strainer should have sufficient openings to admit several times the amount of water necessary to supply the pump, because parts of the strainer may become temporaily clogged and the resistance to the flow of water is at all times considerable when admitted through such small openings. A reduced flow to the pump naturally reduces its efficiency.

HAULAGE METHODS IN QUARRIES.

The ordinary practice of hauling the quarry products to a central point by car or cart and there transferring to an elevator which lifts to the surface is admittedly an uneconomical method of handling and is daily becoming more so as the cost of labor increases. Economy of handling requires that the material be transported from quarry to mill or railroad without any transfer on the way and with minimum attention.

Any one of many different systems of haulage can be used, but the choice must depend on the conditions under which quarrying is carried on and especially on the topography of the country to be traversed.

The first and vital consideration is the extent of the deposit to be worked and the rapidity with which the material is to be handled. Any haulage system involves a considerable outlay, hence where the deposit is small or only a few tons are to be handled daily, a large and expensive equipment is not advisable.

Where the haul is level and the distance does not exceed 1 mile, the use of animals has proven as cheap a power as any, but the haul must begin at the working face of the quarry so that transfer is eliminated.

Where the grades exceed 5 per cent and the haul does not exceed 1 mile, rope haulage has been found an extremely satisfactory and economical system for elevating the material, but requires careful engineering in designing the equipment, especially where a short rise is followed by a long drop. If there is a continuous rise from quarry to terminus the system is especially worthy of consideration.

LOCOMOTIVES.

Steam locomotives are the most economical of all locomotives as regards fuel, provided the grades do not exceed 3 per cent, and are also the cheapest locomotive to install but are somewhat more expensive than other types as regards maintenance and depreciation.

Electric-locomotive haulage is the most modern and in many respects the most economical system. The power may be developed by a waterfall or otherwise at any convenient place and transmitted at high voltage on small wires to the property. Here it is stepped down to the working voltage, and where used at 250 to 500 volts the efficiency attained as regards power consumed is shown to exceed 90 per cent. One of the advantages of the electric locomotive is that it can be used in small units—that is, in moving loads about ton size—and where a heavier load is to be handled two locomotives may be worked in tandem and operated by the same engineer. This shows a big saving over the use of the large steam locomotive when handling small loads. The ordinary electric locomotive is not efficient, however, on grades of more than 3 per cent.

The gear-tooth electric locomotive is especially worthy of consideration for steep grades and where rope haulage is not practical. The gear-tooth type of locomotive is much lighter than the ordinary type and the haulage is dependent only on the power of the motor.

AERIAL TRAMWAYS.

Where the country is extremely rough and the construction and maintenance of a road would involve the building of bridges or the making of wide detours, the use of an aerial tramway recommends itself. The original cost of installation is generally less than with a roadway, and if properly constructed the cost of maintenance is far less. The supporting towers may be 100 or 1,000 feet apart, as the topography of the country demands. The operation of an aerial tramway on any but a straight line adds greatly to the expense and wherever possible curves and angles should be avoided.

Aerial tramways are of the two systems—single cable and double cable. The singles-cable system necessitates the return of all buckets over the sending cable, and this feature causes much delay and has resulted in the almost universal installation of the double-rope system where aerial haulage is used. The single-rope system consists of a single cable, which travels and to which the buckets are attached. The double-rope system has two fixed ropes which constitute the permanent way, and an endless traction rope which draws the buckets out on one rope and returns them over the other.

There are three types of double-rope aerial tramways:

1. The buckets are attached to the traction rope by a clip and are dragged along the stationary rope.
2. The bucket has a clip which seizes the traction rope and remains attached by friction.
3. The buckets are fastened permanently at fixed distances to the traction rope and are filled by a traveling bin which runs above and at the same rate as the buckets.

Each of the three types has many loyal followers and provided a good quality of material is used in the construction, an aerial tramway should be a very desirable and economical method of handling feldspar in the rough country where it is oftenest found.

PREPARATION OF THE FELDSPAR FOR MARKET.

CRUSHING AND PULVERIZING THE FELDSPAR.

The handling of the feldspar from the time it reaches the mill to the time it is delivered on board cars for shipment to the consumer consists of but two steps—crushing and pulverizing. The methods employed to accomplish these two results have changed from time to time, but the result has not changed materially.

DRYING THE CRUDE FELDSPAR.

When the crude feldspar reaches the mill it is often wet from snow or ice in winter or from quarry moisture in the spring. The general practice is to dry the crude feldspar in a vertical kiln or on a hot plate. Neglect of this point causes the fine particles to pack and later to cause trouble in the pulverizing process, but the most valuable result obtained is the elimination of fine dirt which sticks to the lumps of feldspar when wet but can to a considerable degree be shaken loose when dried and the feldspar handled with a steel fork.

Throughout the district investigated no attempt has been made to introduce the rotary drier which has proved so efficient in the drying of cement. This is explained by the fact that it is not necessary to use a drier more than about half the year. The saving made would, however, doubtless justify the installation of a rotary drier as the kiln and the dry plate are both uneconomical and necessitate extra handling of the feldspar.

CRUSHING THE FELDSPAR.

The dry feldspar is ready for crushing. The processes differ in different grinding plants, but they may be divided into two classes: (*a*) Those in which the crude feldspar, after being reduced by sledge to 3 or 4 inches diameter, is fed directly under the rolls of a buhrstone chaser, and (*b*) those in which the crude feldspar is fed into a rock crusher which reduces the feldspar to a maximum of 1 inch in diameter and then goes to the buhrstone chaser mill, which completes the crushing process.

ROCK CRUSHERS.

Rock crushers are of two kinds—jaw crushers, which are intermittent machines, and gyratory crushers, which are continuous machines.

The jaw crusher may be divided into three classes: (*a*) Those with the jaw pivoted at the top, (*b*) those with the jaw pivoted in the center, (*c*) those with the jaw pivoted at the bottom. Type *a*, which is pivoted at the top of the jaw (fig. 15), is the most commonly used in crushing feldspar. The type *b* crusher has a smaller capacity than *a* and no advantages. Type *c* is objected to because the crusher has a tendency to choke at the throat or outlet, and this mass of small rock particles chew into the jaw plates and add much fine iron or steel dust to the crushed product.

Gyratory crushers, like jaw crushers, may also be classed in three types as regards the crushing motion of the spindle: (*a*) Crushers having the greatest movement at the bottom on the smallest lumps, (*b*) those having an equal movement on all sizes of lumps, and (*c*) those having the greatest movement at the top on the largest lumps.

The chief objection to gyratory crushers is the fact that they all have a considerable grinding action which abrades the metal faces and produces more pulverized material than where a simple crushing action is employed. The jaw crushers also exert some abrading action, however, and no crusher having metal crushing faces is devoid of the objection of producing material more or less contaminated with small particles of iron or steel. The operator who employs a crusher of either the jaw or gyratory type has to deal with the problem of cleaning his crushed material of iron and steel particles. The simplest and surest method of accomplishing this result is to screen out all the fine material, because the metal is invariably ground off the plates in very small particles. The objection to this method is the large amount of fine material wasted, which in some cases is as much as 10 per cent of the rock crushed.

Apparatus to eliminate iron and steel particles from dry powdered rock have been only fairly successful and have not come into general use. The most successful method is to use a system of magnets and to have the fine material in the form of a slime or slop. The expense of installing such an apparatus and of drying the cleaned slime will add somewhat to the average cost of crushing the feldspar but will show a big saving as against the rejection of all the dust material from the crusher.

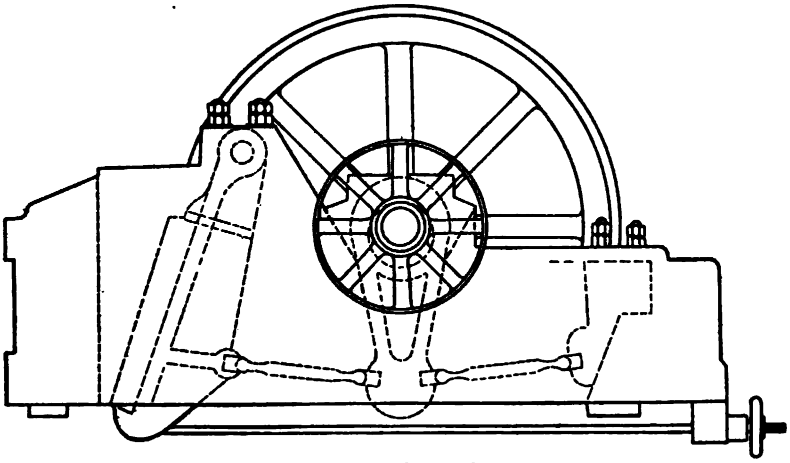


FIGURE 15.—Jaw crusher.

Where the jaw or gyratory crusher has not been introduced the primitive chaser mill is used for crushing the crude feldspar.

THE BUHRSTONE CHASER.

The buhrstone rolls are immense granitic wheels 5 to 6 feet in diameter and 12 to 18 inches in thickness. Two such wheels are mounted on a horizontal shaft and travel around a vertical shaft on a bedplate of granite (fig. 16). This apparatus was for years the only method of crushing feldspar and is to-day in many plants the only apparatus employed for crushing the crude feldspar to a size suitable for grinding in ball mills. The quality of stone used for these great wheels is important because they wear away quite rapidly under the abrading action of the feldspar and any black mica, tourmaline, or other impurity which they contain would go directly into the powdered feldspar. Further, care must be exercised in selection of these rolls because many blocks contain soft spots, and these would wear more rapidly than the rest of the wheel, resulting in a flat wheel. When a wheel is not perfectly round and needs to be reground, which is quite expensive, the power required to turn it over the coarse feldspar becomes excessive.

The mode of feeding a buhrstone chaser is extremely simple and consists in throwing the lumps of feldspar inside the track of the wheels and against the central vertical shaft, from which the bedplate is sloped slightly so that the feldspar slides under the inside edge of the wheel and is crushed. The wheels continue to pass over it until it is forced out over the edge of the bedplate. Here it is collected and passed over a screen, the coarse material from which goes back under the rolls and the fine material goes to the ball mills. The old custom of crushing feldspar lumps 4 to 6 inches in diameter under these rolls causes much more rapid wear than if only small lumps are crushed, hence the willingness of the operator to risk iron contamination by introducing the jaw or gyratory crusher for preliminary breaking, in order to lengthen the life of the rolls, which are expensive and short lived at best.

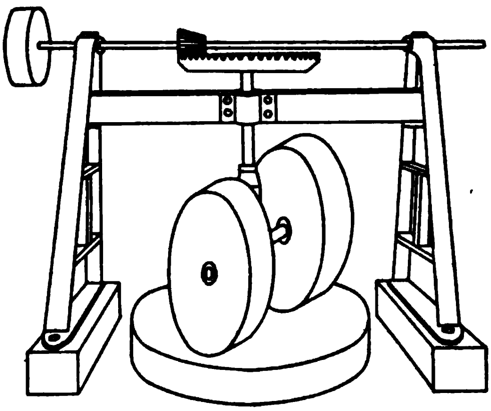


FIGURE 16.—Buhrstone mill.

If the feldspar has been subjected to a preliminary breaking before going to the chaser, the output of the chaser is greatly increased, but the treatment necessarily remains the same.

The sole objection to both the jaw and gyratory crusher is the contamination of the feldspar with iron particles. The introduction of buhrstone faces for the fixed and movable jaws should practically eliminate this difficulty. The buhrstone plates must of necessity be many times thicker than the steel plates which they would replace, but the frame of the crusher could be easily remodeled to provide for this.

Whatever the method of crushing, whether a combination of breaker and chaser, or treatment by the chaser alone, the feldspar must be reduced to a size which will pass a 10-mesh sieve dry in order to obtain an economical operation in the pulverizing mills.

SIEVING THE CRUSHED FELDSPAR.

For separating the coarse feldspar from the part ready for pulverizing, the revolving sieve or trommel is almost universally employed. The vibrating and shaker sieves are less efficient, owing to the presence of some flake mica, which wedges into the meshes of the sieve and prevents the fine feldspar from passing through. Every part of the sieve on the revolving type is inverted with each revolution, causing the mica particles to fall loose and pass out with the coarse material.

SEPARATING THE MICA FROM THE FELDSPAR.

The presence of the mica is considered by most users as highly objectionable, and this is doubtless true particularly when the flakes are of appreciable size. It would therefore seem highly desirable to remove the mica from the coarse material from the sieve before returning it to the machine for recrushing.

The mica in this material is chiefly thin flakes which have been completely separated from the feldspar with which the mica was originally intimately crystallized. A small amount will still adhere to feldspar particles, but this material can safely be returned to the chaser and the mica will probably be loosened in the next crushing. The separation of the mica from the crushed feldspar by an air blast or by flotation is perfectly feasible. The particles of feldspar in the crushed state approach cubes in form, whereas the mica is generally reduced to flakes, so that the mica may be carried by air or water much more readily than the feldspar and a separation effected. If no provision is made for removing the mica it will continue to be returned to the chaser and ultimately be pulverized. The presence of mica will not only reduce the quality of the feldspar, but its resistance to abrasion will increase the cost of pulverizing the feldspar.

PULVERIZING THE FELDSPAR.

The feldspar, after being crushed to a maximum size of 10 mesh, is ready for the pulverizer. The pulverizing may be accomplished by either wet or dry grinding, although the dry grinding process is now exclusively employed in the United States.

Wet grinding or pulverizing has been employed extensively throughout Europe. The machinery used consists of a broad shallow vat floored with smooth granite blocks and having a central vertical shaft with two horizontal arms. To each arm is attached a great granite or buhrstone block, which, as the shaft revolves, are dragged over the bed of the vat and crush the feldspar between them and the granite floor of the vat. In operation, the crushed feldspar is fed into the vat with sufficient water to produce a thin slip when the feldspar is properly pulverized. The traveling of the loaded arms around the vat keeps the water in motion and the feldspar goes into suspension as soon as it becomes fine enough. This method of grinding is expensive, but produces a very fine grade of product. It is still employed in many plants for the pulverizing of the materials to be used in glazes.

Wet grinding is also done in some plants in Europe by means of ball mills. This process does not differ materially from dry grinding in ball mills, as is described later. The essential difference consists in using water in the charged mill, in quantity sufficient to float the pulverized material, so that it does not interfere with direct contact between the pebbles and the coarse feldspar. The objection to wet grinding or wet pulverizing is the added expense of drying the pulverized material before it can be shipped any distance. In many European plants feldspar is ground only for private consumption, and in this case can be pulverized more economically than by the dry process. In some towns it is ground wet and sold locally in the wet state known as "slop," but this is impractical except where the haul is very short.

Pebble mills for dry grinding, as practiced in the United States, are of three different types: (*a*) Ball mills, (*b*) tube mills, (*c*) conical mills.

BALL MILLS.

Ball mills are the oldest form of this class of grinding machinery. They are made in all dimensions up to 8 feet diameter and 10 feet long. The construction of the mill is as follows: The cylinder is of heavy sheet steel riveted to heavy heads of cast iron, into which supporting shafts are shrunk. The cylinder is lined, both circumference and heads, with blocks of silex or vitrified porcelain. The grinding is effected by means of flint pebbles 2 to 3 inches in diameter, with which the mill is charged. The grinding action depends on the speed of revolution and the weight of the charge of pebbles. If the charge of pebbles and material to be ground fill only a small part of the interior of the mill, and the mill is run at a low speed, the pebbles will rise with the moving mill and roll back to the bottom only when gravity demands. If the speed is increased they are carried farther up and instead of rolling back, drop to the center of the mill. If the speed is too great, the pebbles are held against the circumference of the mill by centrifugal force and do not move, thus doing no grinding.

If the charge of pebbles and material to be ground fill the mill's interior above the center there is practically no action on the material except that of abrasion exerted by the pebbles sliding and rolling under the weight of those above. Different operators make very different claims as to what speed and charge are most economical and efficient, but it is generally claimed that for feldspar grinding the conditions last described, in which the action is largely abrasive, as the mill is more than half filled with pebbles and material, produces the largest tonnage of pulverized feldspar per horsepower consumed.

That period required to grind a given charge to pass any given sieve is determined by test, and the data obtained is made the basis of operation. Most companies, however, sample and test the material by sieves before emptying the mill, and this practice is to be strongly encouraged, as only in this way can the operator be certain of the quality of the output.

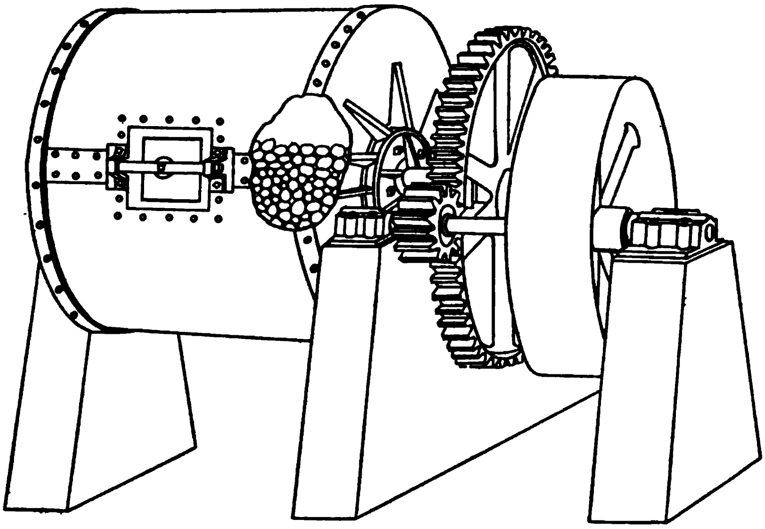


FIGURE 17.—Ball mill.

The mill (see fig. 17) is charged and discharged through a door in the shell midway between the heads. The operation is periodic, the mill being stopped, the door opened, and the charge shoveled or dumped into the mill. The charge being ground, the mill is stopped only long enough to exchange the tight door for one full of holes of sufficient size to permit the powdered material to pass out, but to retain the grinding pebbles. The mill is set in motion and in revolving empties itself. This method of emptying the mill causes an enormous amount of dust throughout the plant and would seem to require that the mills be inclosed in dust-tight coverings. No such precautions are taken, however, and only in a few instances is any attempt made to box the mills in order to prevent the escape of the feldspar dust, which is the most valuable part of the product. The ground feldspar is generally shoveled into carts or wheelbarrows and removed to the stock bins or loaded directly into box cars for shipment.

TUBE MILLS.

Tube mills (fig. 18) are probably the most economical and in many respects the most efficient machine available for feldspar pulverizing. They are long steel cylinders with heavy cast-iron heads, and are of two types—namely, "axial supported," in which the mill revolves on two hollow steel trunnions, and "roller supported," in which the cylinder is fitted with a broad flat tire about its circumference near one end and a cog-faced tire near the other end. The machine rests on rollers and cogwheels, which provide the power for revolving the cylinder. The tube mill is lined, like the ball mill, with silex or porcelain blocks, and is charged with flint pebbles. The cylinder is set on a slight slope, so that the sand fed into it at the high end works its way down and out at the opposite end, being pulverized on the way. The feldspar is fed continuously to the mill through an opening in the center of the axle, and when it reaches the opposite end it passes out through the center of the axle at that end. In some mills the outlet is by small holes in the periphery of the mill. The number of revolutions which the material makes between entrance and exit and hence the fineness to which it is ground depends upon the slope of the mill. The quantity of pebble charge and the rate at which the material is fed to the mill are also factors that require attention, especially in the center discharge type. Too heavy feed forces the semiground material forward and out of the mill before it is properly pulverized, whereas the larger the pebble charge the smaller the charge of material that can be fed without causing it to rise above the overflow at the outlet.

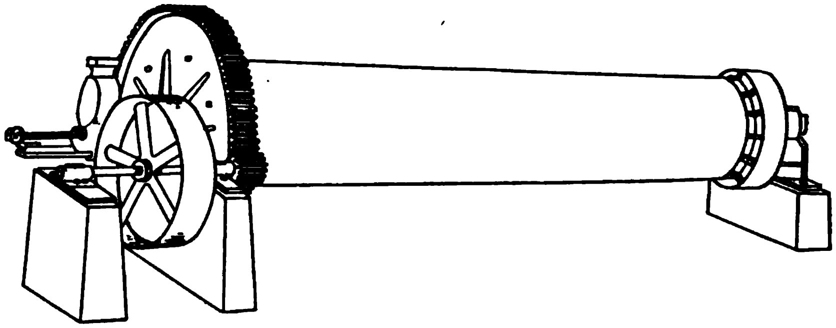


FIGURE 18.—Tube mill.

CONICAL MILLS.

The conical mill was developed from the tube mill inasmuch as it consists of a long drum into which the material to be ground is introduced at one end and is expelled at the other end, being crushed in the passage by means of silex pebbles. The essential difference from the tube mill is the shape of the drum, which is a single or double cone. The effect of this cone is a classification of the grinding pebbles, the largest remaining in the part of the mill having the greatest diameter and the smaller pebbles grading themselves toward the outlet of least diameter. The material being pulverized also tends to classify itself according to size, not traveling to the outlet end until it has reached a certain fineness. These mills are built in a variety of diameters and lengths adapted to the reduction of different rock minerals. They are lined with silex blocks or vitrified porcelain in the same manner as are the ball and tube mills.

Conical mills have not up to the present time proved effective for the ultimate pulverization of feldspar, although they are reported as very economical and efficient in reducing the crushed rock to a size which enables the grinding period in the ball or tube mill to be reduced to the minimum.

BOLTING.

The practice of bolting the ground feldspar in order to remove the part which has not been sufficiently pulverized has never been practiced, although various attempts to introduce such a process have been made. The pulverized feldspar appears to take up a small amount of hygroscopic moisture, which causes it to pack on any fine sieve. If such a process was introduced it would necessarily have to be preceded by a thorough drying temperature well above 100° C. and the dry powder passed through the bolting mill at a temperature above 100° C. The maintenance of an equipment for such treatment is of doubtful value in view of the fact that where used for ceramic manufacture the pulverized feldspar is mixed with other materials which contain a small content of refuse that must be eliminated and the mixture receives a treatment which removes any coarse particles. It therefore appears sufficient to make a sieve analysis of samples carefully taken from the pulverized material and thus determine the exact degree of pulverization.

WATERING.

A common practice in many plants is the wetting down of the pulverized feldspar, presumably to prevent loss of the very fine part of the ground mineral. This practice is of doubtful value, as ground feldspar will quickly absorb from the air enough moisture to prevent its flowing. The addition of any water in excess of this amount must be paid for as feldspar, and freight from mill to user must also be paid on this water. Another and important consideration where feldspar is shipped in bulk in box cars is the tendency of damp feldspar to absorb stains from the boards which line the floor and sides of the cars.

Bagging the feldspar as it comes from the pulverizing mill has been found a very economical practice by some operators, as it reduces handling to the minimum if the plant is not equipped to mechanically convey the material to storage bins from which it can be loaded by gravity into cars for shipment. The protection from contamination which bagging insures is also worthy of consideration.

Where the feldspar is loaded loose in the car the practice of lining the interior of the car with cheap paper is recommended. If properly done, this paper lining will insure against loss through small openings in the floor and around the doors.

EFFECT OF TIME ON GRINDING OF FELDSPARS.

The degree of pulverization has long been known to exert a pronounced effect on the value of the feldspar in ceramic mixtures, but no specific data are available whereby a standard time of grinding can be chosen, for the reason that the degree of pulverization depends upon a number of factors.

Chief among these are the following: Speed (revolutions per minute) of the grinding cylinder, weight of the charge of pebbles in the cylinder, proportions of the various-sized pebbles in the cylinder, weight of the charge of crushed feldspar in the cylinder, degree of fineness to which the crude feldspar is reduced before being introduced into the cylinder, condition of the crude feldspar as regards temperature and moisture content, the physical properties of the particular feldspar being ground.

Any difference in the conditions under which grinding is effected would seriously affect the rate of pulverization.

The user of feldspar is concerned only with the degree of fineness to which the material is reduced, and the details of the grinding process need not interest him except as they influence the quality or price of the material obtained.

The proportions of the various-sized particles obtained by a standard system of grinding under uniform conditions and ground for stated lengths of time should be a valuable aid in choosing a standard degree of fineness. The increased pulverization obtained by grinding for longer periods should furnish data whereby the most practical degree of pulverization may be obtained and beyond which increased grinding does not produce a proportionate increase in fineness.

TESTS TO DETERMINE EFFECT OF TIME ON DEGREE OF FINENESS.

To determine these data a series of pulverized feldspar samples of a standard Maine feldspar were obtained. These had been pulverized under exactly similar conditions for definite lengths of time as follows: Sample of crude feldspar crushed by buhrstone chaser ready for ball mill; four samples of the same feldspar after grinding 6, 8, 10, and 12 hours in the ball mill, respectively.

CLASSIFICATION METHODS USED.

In order to determine the percentage proportions of the different sizes of grains contained in these samples, two systems of classification were followed: (*a*) Sieve, (*b*) elutriator.

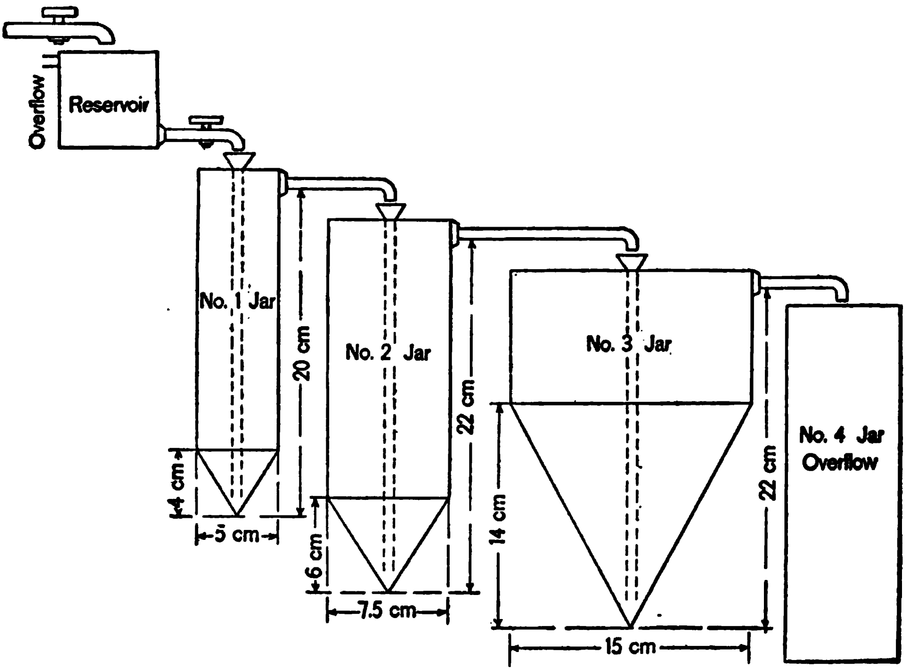


FIGURE 19.—Schultze elutriation apparatus. Flow, 1.2 c. c. per second; hydraulic values—No. 1 jar, 0.068, No. 2 jar, 0.03, No. 3 jar, 0.0075.

For the sieve classification bronze cloth sieves, ranging in fineness up to 330 mesh per linear inch were used. For classification of the material passing 330-mesh sieve the Schultze elutriator was employed.

SCHULTZE ELUTRIATION APPARATUS.

The Schultze elutriation apparatus consists of a series of three jars 5, 7.5, and 15 c. m. in diameter, respectively, with conical bases and straight sides. A quantity of feldspar is placed in the smallest jar, into the base of which water under a given head is admitted (fig. 19).

The current rising through the jar conveys all particles that it can support into a tube connecting with the base of the second jar. This jar being of greater cross-sectional area, the water rises through it at a slower rate than the water in the first jar. Some of the particles supported by the current in the first jar and carried over to the second are too heavy for the weaker current in the second jar and fall to the bottom. The overflow from the second jar is conveyed by a tube to the base of the third jar, which is of greater diameter than the second jar. In this jar the separation of still smaller particles is effected and material fine enough to be supported by the current flowing up through the third jar is conveyed to a fourth jar, where it settles. In this way the original sample is divided into four parts that differ in fineness.

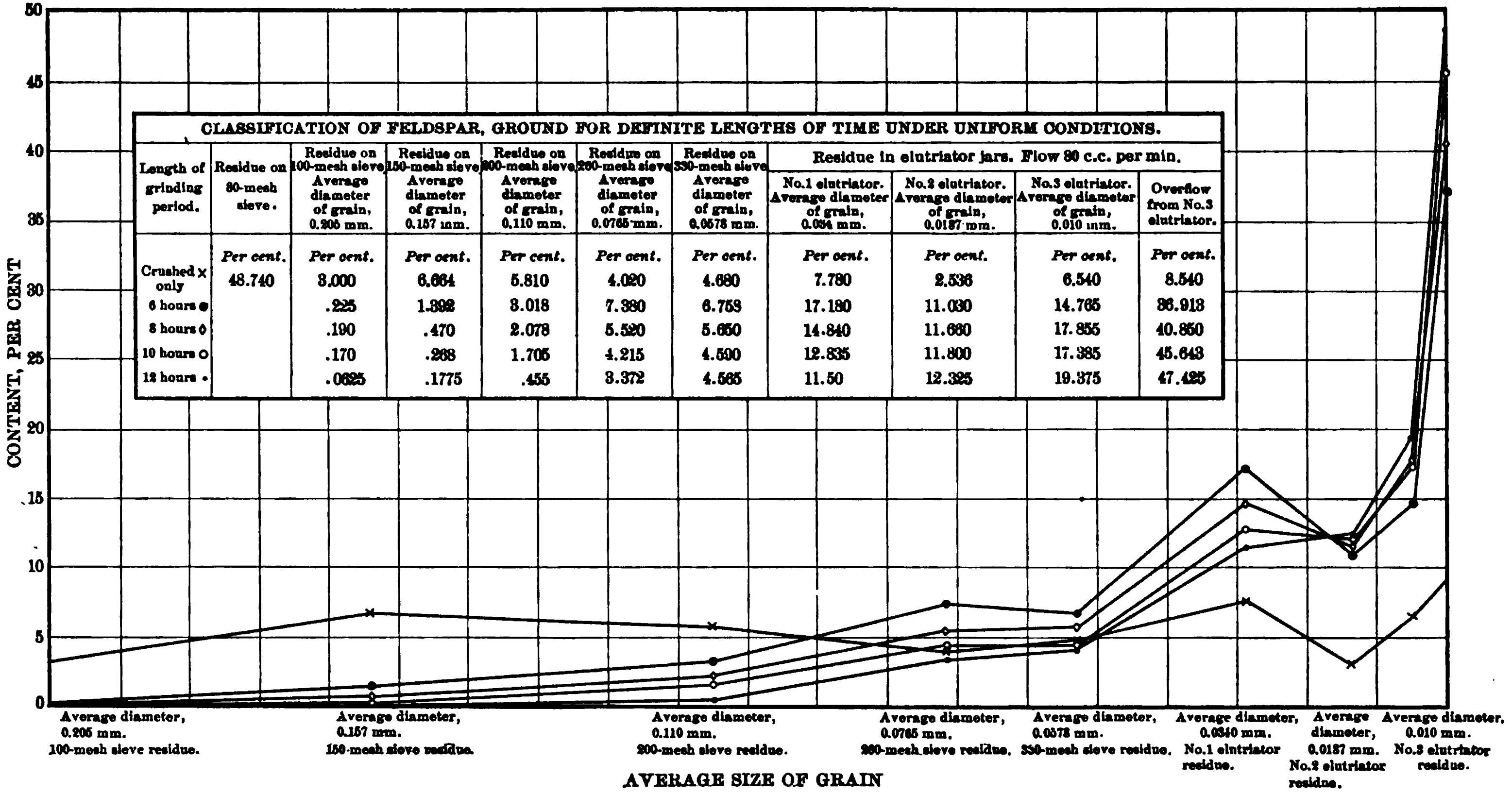
As the particles removed by the different jars of this apparatus are determined by their size and specific gravity and shape, and also by the rate of flow of water in the apparatus, the various divisions of particles are expressed in hydraulic values.

The hydraulic value of a given particle of any material is the rate of vertical flow of water, expressed in cubic centimeters per second, necessary to sustain that particle in suspension in water. By regulation of the flow in the elutriator, the following classification was obtained in the different jars. With an overflow of 80 c. c. per minute, No. 1 jar has a hydraulic value of 0.0679; No. 2 jar, 0.0302; and No. 3, 0.0075. The overflow from No. 3 jar furnishes a fourth classification. The size of grains obtainable with these different hydraulic values was determined by actual measurement of the classified material by the aid of the microscope. The classification was all effected in the wet way, and an abundance of water was employed to insure as perfect a classification as possible. In order to collect the fine slime which overflows from the last elutriator jar the water carrying it in suspension was collected in a large jar and to this was added about 2 c. c. of concentrated hydrochloric acid. The slime precipitates in about an hour and the excess water can be siphoned off. The classifications were dried at 100° C. and weighed, after which the microscopic measurements were made.

RESULTS OF TESTS.

Figure 21 shows that the increased pulverization obtained by longer grinding under these conditions is nearly proportional to the time of grinding. The choice of a rate of flow for the elutriator was slightly out of accord with the other classifications, but this was gaged by the size of grains desired in the different classes. It is especially worthy of note that the ratios between the proportion of material removed by each classifier was regular.

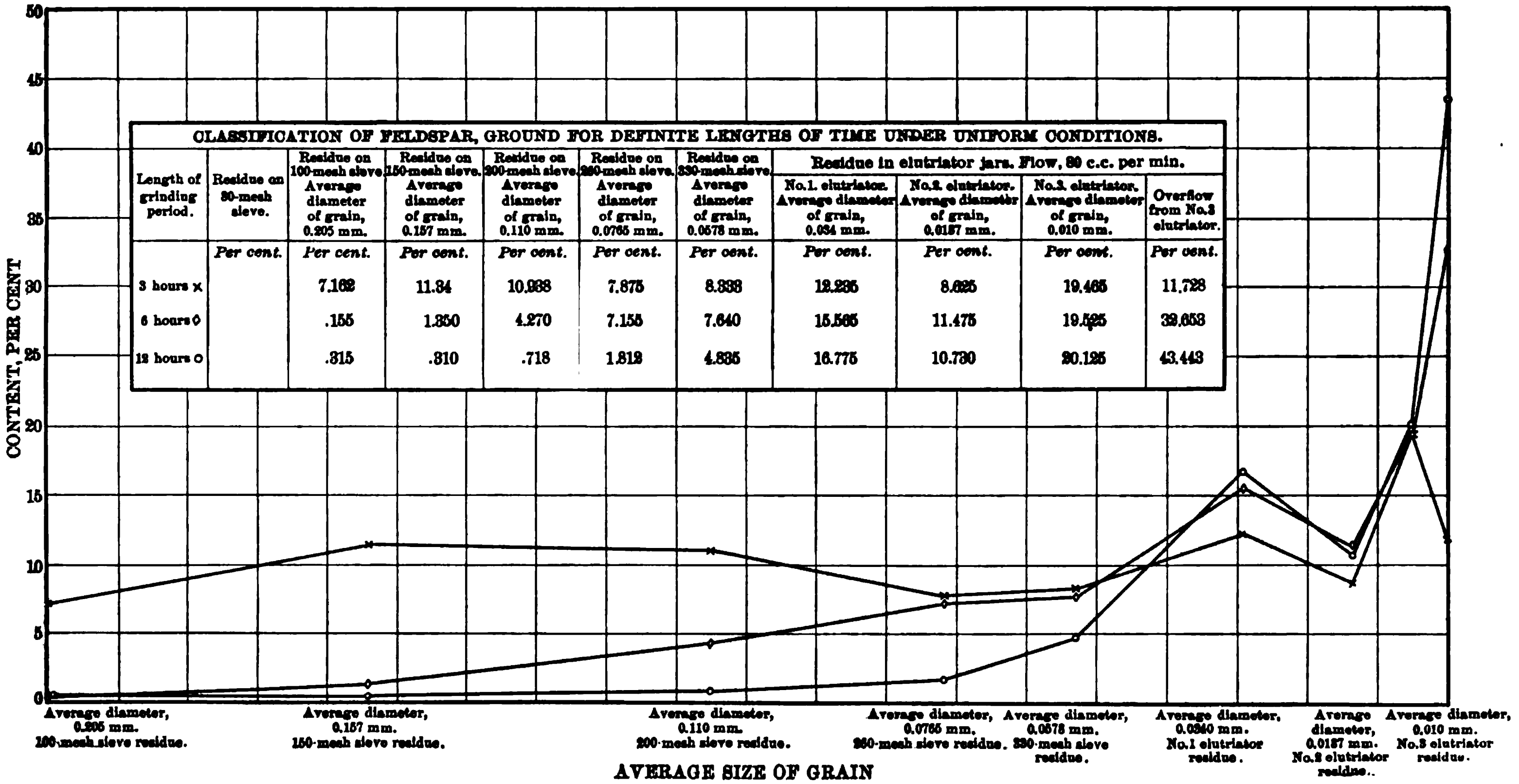
A similar investigation was conducted with samples of Connecticut feldspar ground under uniform conditions for stated lengths of time,



CLASSIFICATION OF FELDSPAR, GROUND FOR DEFINITE LENGTHS OF TIME UNDER UNIFORM CONDITIONS.

Length of grinding period.	Residue on 80-mesh sieve.	Residue on 100-mesh sieve Average diameter of grain, 0.205 mm.	Residue on 150-mesh sieve Average diameter of grain, 0.157 mm.	Residue on 200-mesh sieve Average diameter of grain, 0.110 mm.	Residue on 260-mesh sieve Average diameter of grain, 0.0765 mm.	Residue on 330-mesh sieve Average diameter of grain, 0.0578 mm.	Residue in elutriator jars. Flow 80 c.c. per min.			
							No.1 elutriator. Average diameter of grain, 0.034 mm.	No.2 elutriator. Average diameter of grain, 0.0187 mm.	No.3 elutriator. Average diameter of grain, 0.010 mm.	Overflow from No.3 elutriator.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Crushed × only	48.740	3.000	6.664	5.810	4.020	4.680	7.780	2.536	6.540	8.540
6 hours ●		.225	1.392	3.018	7.380	6.753	17.180	11.030	14.765	36.913
8 hours ◊		.190	.470	2.078	5.520	5.650	14.840	11.660	17.855	40.850
10 hours ○		.170	.268	1.705	4.215	4.590	12.835	11.800	17.385	45.643
12 hours •		.0625	.1775	.455	3.372	4.565	11.50	12.325	19.375	47.425

FIGURE 20.—Results of classifying test of Maine feldspar.



CLASSIFICATION OF FELDSPAR, GROUND FOR DEFINITE LENGTHS OF TIME UNDER UNIFORM CONDITIONS.

Length of grinding period.	Residue on 80-mesh sieve.	Residue on 100-mesh sieve. Average diameter of grain, 0.205 mm.	Residue on 150-mesh sieve. Average diameter of grain, 0.157 mm.	Residue on 200-mesh sieve. Average diameter of grain, 0.110 mm.	Residue on 260-mesh sieve. Average diameter of grain, 0.0765 mm.	Residue on 330-mesh sieve. Average diameter of grain, 0.0578 mm.	Residue in elutriator jars. Flow, 80 c.c. per min.			
							No.1. elutriator. Average diameter of grain, 0.034 mm.	No.2. elutriator. Average diameter of grain, 0.0187 mm.	No.3. elutriator. Average diameter of grain, 0.010 mm.	Overflow from No.3 elutriator.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
3 hours ×		7.162	11.34	10.938	7.875	8.338	12.235	8.625	19.465	11.728
6 hours ◇		.155	1.350	4.270	7.155	7.640	15.565	11.475	19.525	39.653
12 hours ○		.315	.310	.718	1.812	4.835	16.775	10.730	20.125	43.443

FIGURE 21.—Results of classifying test of Connecticut feldspar.

and although a series large enough to make the data as comprehensive as in the foregoing investigation was not obtained, nevertheless the striking similarity of the results obtained and the fact that this series contains a three-hour sample, which is lacking in the other series, makes the presentation of the data advisable. The results are shown in figure 22.

DISCUSSION OF RESULTS.

The size of ball mill and operating conditions employed in the production of these samples varied considerably from that of the first series, but the ratio between the proportions of the different sized grains did not vary more than might be expected in a duplication of test on one mill.

The results of the three-hour grind are especially interesting because the percentage of the finest grains is lower than would be expected. The very low values obtained from these coarse feldspars when employed in ceramic mixtures are thus accounted for, as the distribution of different sized particles throughout the mixtures can not be sufficient to cause uniform vitrification of the mass.

As an indication of the influence of the size of grain on the temperature at which a feldspar may be expected to become active as a flux or solvent of other silicates, the products of the classification process were made into cones similar to the standard pyrometric cones and were subjected to deformation tests against standard cones. The results are shown graphically in figure 23.

The cones of that part coarser than 0.110 mm. would not hold their form during the early stages of firing, crumbling like sand as soon as the dextrine which was used in forming them burned away. Hence no data on the coarser grades of feldspar is available.

The results obtained indicate that the finest part deforms at least two cones (40° C.) earlier than the grains having an average diameter of 0.11 mm. and about one cone (20° C.) earlier than the grains having an average diameter of 0.0187 mm.

This data is the result of tests made on one feldspar only, but the pronounced variation in deformation temperature with variation of size of grain would indicate that a marked improvement in vitrifying power would result from increased pulverization regardless of the particular type of feldspar.

HANDLING THE FELDSPAR FROM QUARRY TO CONSUMER.

The cost of pulverized feldspar in the United States is materially increased by the repeated handling of the feldspar before, during, and after grinding. In some instances the feldspar is loaded onto wheelbarrows and removed to a clear space in the quarry, where it is unloaded and broken by sledge into pieces small enough for hand sorting. After hand sorting the good feldspar is loaded on a car or wagon and hauled outside the quarry. Here it is unloaded and

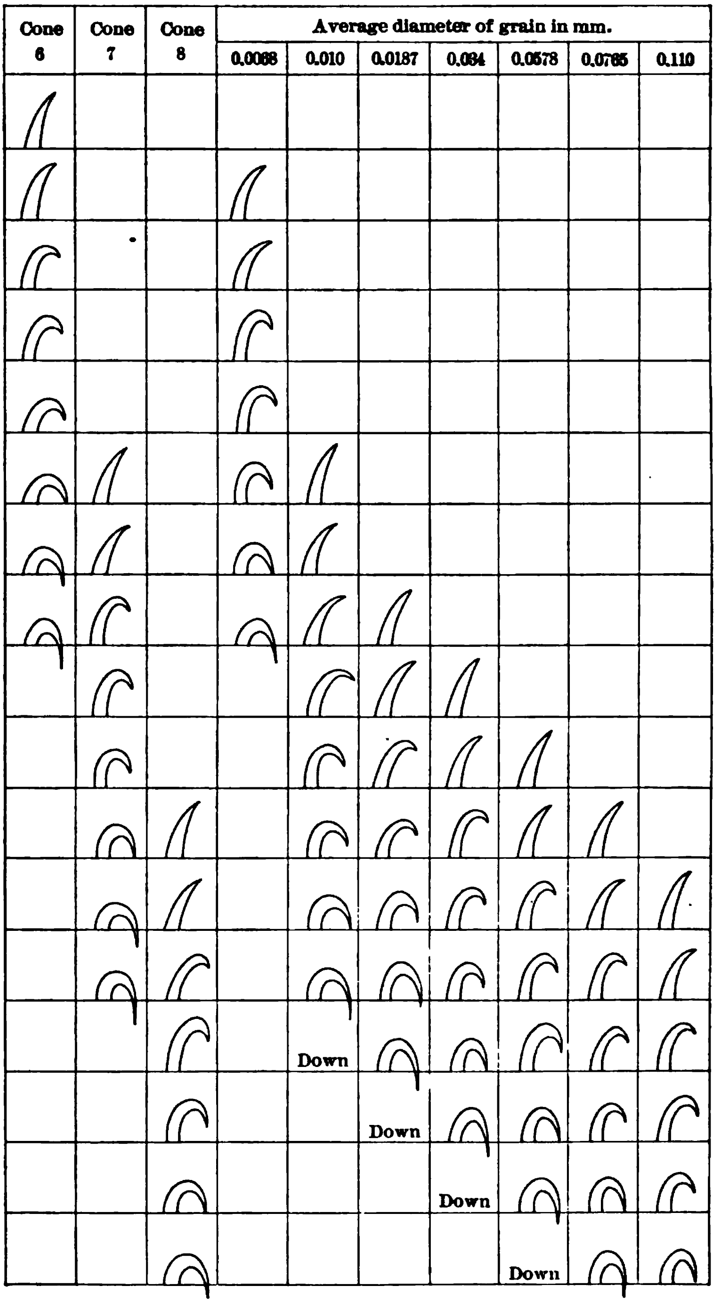


FIGURE 22.—Deformation tests of feldspars of different fineness.

stacked in bins. From these bins it is loaded into wagons, hauled to the railroad, and loaded into cars. After transportation to the grinding mill it must in some instances be loaded into wagons and hauled to the mill, where it is stored in sheds or bins on the ground level. Thus the crude feldspar is handled 8 or 10 times before it begins the grinding process.

From the sheds or bins the crude feldspar is loaded on wheelbarrows, cars, or wagons and hauled to the crusher, which is of either the jaw or roll type, dumped in a heap before this machine, and fed into it by hand as required. From the crusher it is generally elevated by conveyer to hopper bins above the ball mills, which are filled by removing a gate in the bottom of the hopper. After grinding in the mill the pulverized feldspar is discharged on the floor beneath the mill, shoveled into carts or cars, and wheeled to the stock bin, where it is stored until sold. The final handling consists in loading into wagons and hauling to the car, where it must be unloaded and shoveled or wheeled in wheelbarrows from the car entrance into the ends of the car. Thus the feldspar is handled perhaps seven times more, making a maximum of 17 handlings from the time it is shot loose in the quarry until it is delivered f. o. b. cars for the consumer.

In most of the feldspar mills in this country the total number of handlings does not reach the maximum, but where a saving is made at one point a loss occurs at another, so that the number of handlings rarely falls below 12. The installation of conveyers and tramways could save much of this handling, but the operator considers the investment too great to be considered in most cases. Furthermore, the uncertainty of the continuity of the dike beyond that actually exposed makes operators overcautious of expensive installations which can not be readily removed and erected on other properties.

CHEMICAL ANALYSES OF SAMPLES.

In the course of this investigation a large number of feldspar deposits were visited and samples collected. Some of these samples were subsequently analyzed and their pyrometric properties determined by testing in a standard porcelain mixture made as previously described.

The results of the analyses of some of the samples are given in the table following. In the first column of this table the numbers of the deposits correspond with those in Plates IV to VIII and in subsequent descriptions. Samples designated as A were analyzed in the laboratory of the Bureau of Mines at Pittsburgh, Pa.; those designated as B were analyzed by Robert Back, under the direction of C. L. Parsons, in the Washington laboratory of the bureau; and those designated C were analyzed for the Bureau of Mines by D. J. Demorest, of Ohio State University, Columbus, Ohio, in the laboratory of that university. The table follows.

TABLE 1.—*Results of analyses of feldspars and pegmatites.*

No. of deposit.	Laboratory.[a]	Character of sample.	Deposit.			Composition.										
			Town or place.	County.	State.	Ignition loss.	SiO_2.	Al_2O_3.	Fe_2O_3.	TiO_2.	CaO.	MgO.	BaO.	K_2O.	Na_2O.	Total.
						Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
2	A	Potash feldspar	New Castle	Lincoln	Maine		64.67	19.18	0.20		0.99	Trace.		12.76	2.54	100.34
11	A	do	Cathance	Sagadahoc	do	0.33	73.89	14.33	.16		Trace.	Trace.		9.2	2.14	99.87
14	A	Pegmatite	do	do	do		74.34	14.45	.14		Trace.	Trace.		8.63	2.00	99.56
14	A	Pure feldspar in graphic granite.	do	do	do		65.07	19.39	.10		Trace.	Trace.		12.58	2.52	99.66
20	A	Graphic granite	Georgetown Peninsula.	do	do	.30	74.53	14.26	.16		Trace.	Trace.		8.55	2.25	100.05
21	A	Feldspar	Phippsburg Basin	do	do	.25	64.90	19.75	.12		.00	Trace.		12.04	2.68	99.74
22	A	do	Auburn	Androscoggin.	do		67.81	18.55	.08		.21	.07		9.32	4.27	100.31
31	A	do	Hebron	Oxford	do		65.48	19.39	.08		.00	Trace.		11.51	2.85	99.31
33	A	Soda feldspar	Mount Apatite	Androscoggin.	do	.16	66.36	21.35	.12		1.10	.21		.73	9.74	99.77
35	A	Graphic granite	do	do	do	.75	71.55	18.11	.16		.46	Trace.		.64	8.72	100.39
43	A	Feldspar	Norway	Oxford	do	.13	64.97	19.48	.04		.00	Trace.		11.76	2.56	99.94
48	A	do	So. Glastonbury	Hartford	Connecticut		65.64	19.11	.14		Trace.	Trace.		12.58	2.32	99.79
50	A	do	Portland		do	.25	65.24	19.74	.12		.00	.00		11.84	3.04	100.23
53	A	do	Middletown		do		66.03	18.99	.08		.00	.00		10.96	3.12	99.18
58	B	Microcline	Crown Point	Essex	New York	.40	63.61	19.09	.43	0.02	1.73	.54	0.17	.15	14.07	100.21
59	B	do	Ticonderoga	do	do	.18	64.55	18.90	.36	.03	.51	.19	.19	12.32	2.88	100.11
59	B	Andesine	do	do	do	.58	59.35	25.30	.57	.03	6.43	.00	Trace.	1.35	6.26	99.87
62	B	Feldspar	Batchellerville	Saratoga	do	.26	65.14	19.38	.29	.01	.44	.14	.00	11.28	3.61	100.55
62	B	Salmon feldspar	do	do	do	.17	64.26	18.78	.43	.00	.33	.14	.00	14.15	2.01	100.27
66	B	Andesine	Cranberry	Fulton	do	.54	61.91	23.69	.40	.00	4.37	.13	.00	1.17	8.40	100.61
67		Feldspar	Bedford	Westchester	do	.28	69.45	16.76	.20		.45	.05	.10	2.60	9.80	99.69
68	B	Salmon microcline	do	do	do	.22	64.82	18.87	.29	.01	.23	.16	Trace.	13.11	2.70	100.41
68	B	Albite pegmatite	do	do	do	.40	73.88	15.73	.36	.01	.86	.36	.00	.48	7.97	100.05
71	C	Microcline	Darlington	Delaware	Pennsylvania	.12	64.70	19.60	.03	.00	.05	.00	.00	11.87	3.76	100.13
72	C	Microcline pegmatite	Chester Heights	do	do	.33	73.35	14.60	.06	.00	.06	.00	.00	9.11	2.00	99.51
72	C	Albite pegmatite	do	do	do	.42	74.60	15.66	.05	.00	2.75	.00	.00	.65	6.33	100.46
78	C	Buff microcline	Mendenhall	Chester	do	.21	64.36	20.01	.20	.00	.46	.00	.00	12.44	2.48	100.16
78	C	Albite pegmatite	do	do	do	.60	67.93	20.49	.30	.00	2.60	.00	.00	.80	6.95	99.67
80	C	Graphic granite	New Garden	do	do	.30	72.39	15.57	.20	.00	.13	.00	.00	9.55	2.27	100.41
81	C	do	Pomeroy	do	do	.24	67.87	17.82	.15	.00	.12	.00	.00	10.93	3.33	100.40
89	C	Albite	Sylmar	do	do	.83	67.47	20.05	.15	.00	.24	.00	.00	.86	9.74	99.34

89	C	Magnesium aluminum silicate.[b]	.....do	.....do	.....do	17.30	45.46	13.49	.05	.04	.08	23.28	.00	.30	.16	100.16
96	C	Pegmatite	Marriotsville	Howard	Maryland	.39	65.83	19.48	.20	.00	.00	.00	.00	11.33	1.87	99.10
101	C	Microcline pegmatite	Woodstock	.....do	.....do	.13	74.20	14.30	.20	.00	.00	.00	.00	9.48	1.59	99.90
101	C	Albite pegmatite	.....do	.....do	.....do	.76	65.32	22.00	.21	.00	3.78	.00	.00	1.06	6.89	100.02
105	....	Feldspar	Lowry	Bedford	Virginia	.10	68.75	18.56	.03	Trace.	1.25	Trace.	....	6.85	4.29	99.83

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[a] Samples designated A were analyzed in the Bureau of Mines laboratory at Pittsburgh, Pa., those designated B, in the Bureau of Mines laboratory at Washington, D. C., and those designated C by D. J. Demorest, at Ohio State University, Columbus, Ohio.

[b] Along walls of dike from which No. 89-a was taken.

FELDSPAR QUARRIES, MINES, AND PROSPECTS:

The feldspar deposits that were investigated during the course of this investigation are briefly described in the pages following. Their location is shown in Plates IV to VIII. The numbers used to represent the deposits correspond to those used in Tables 1 and 2, and in the detailed descriptions of the deposits.

TABLE 2.—*Location of the feldspar quarries, mines, and prospects, including some mica and gem mines, shown in Plates IV to VIII.*

No.	Deposit.	State.	County.	Location.
1	Pegmatite dike	Maine	Hancock	East Orland, in.
2	John Glidden property.	do	Lincoln	New Castle, 2 miles west of.
3	Abandoned quarry	do	do	Edgecomb, in.
4	Hull property	do	do	Do.
5	Noble prospect	do	Sagadahoc	Georgetown Peninsula.
6	Smith prospect	do	do	Do.
7	Alfred Graves quarry	do	do	Cathance, 2 miles north of.
8	Maine feldspar quarry	do	do	Adjoins quarry No. 7.
9	Maine graphic granite quarry.	do	do	Cathance, 2½ miles northwest of.
10	Trenton quarry	do	do	Cathance, 2 miles northwest of.
11	Old W. G. Willis quarry.	do	do	Cathance, 1 mile west of.
12	Old Golding quarry	do	do	Adjoins quarry No. 11.
13	New W. G. Willis quarry.	do	do	South of Nos. 11 and 12.
14	Fisher quarry	do	do	South of No. 11.
15	Maine Feldspar Co. deposit.	do	do	Topsham, 2 miles east of.
16 17	Mt. Ararat quarries	do	do	Topsham, 1 mile north of.
18	Mason property	do	do	Riggsville, near, on Georgetown Peninsula.
19	Noble deposit	do	do	Riggsville, near.
20	Golding quarry	do	do	Georgetown Peninsula.
21	Joseph B. Perry quarry.	do	do	Phippsburg, near.
22	Pegmatite dike	do	Androscoggin	Auburn, 1½ miles south of.
23	do	do	do	South of No. 22.
24	do	do	do	East of No. 23.
25	Staple Point deposit	do	Cumberland	South Freeport, near, on Staple Point.
26	Old Knox quarry	do	Oxford	Dixfield, 3½ miles southwest of.
27	Mount Mica deposit	do	do	South Paris, 5 miles northeast of.
28	Buckfield district	do	do	Owls Head, north of.
29	Hooker Ridge dike	do	do	South Paris, 1½ miles east of.
30	No. 4 Hill quarry	do	do	Hebron, in.
31	Hibbs quarry	do	do	Do.
32	Mount Rubellite deposit.	do	do	Paris Hill post office, north of.
33	Pulsopher deposit	do	Androscoggin	Auburn, about 4 miles west of, on west slope of Mount Apatite.
34	Towne quarry	do	do	Near and southeast of deposit No. 33.
35	Greenlaw quarry	do	do	Auburn, 3½ miles west of, on top of Mount Apatite.
36	Maine quarry	do	do	Auburn, 3 miles west of.
37	do	do	do	East of quarry No. 36.
38	Pegmatite deposit	do	do	Auburn, about 3½ miles west of, on south slope of Mount Apatite.
39	Havey quarry	do	do	Auburn, 3½ miles west of, south of Mount Apatite.
40	Berry quarry	do	do	Adjoins Havey property.
41	Charles Sawyer deposit.	do	Cumberland	Auburn, 4 miles west of, at Rumford Junction.
42	Dow property	do	do	West of Sawyer property.
43	Stevens ledge	do	Oxford	Norway, 2 miles northeast of.
44	Curtis quarry	Connecticut	Hartford	South Glastonbury, 3 miles east of.
45	Wiarda quarry	do	do	South Glastonbury, near.
46	Old Wiarda quarry	do	do	South Glastonbury, 1 mile south of.
47	Old Eureka quarries	do	do	South Glastonbury, 1¾ miles south of.
48	Louis W. Howe quarry	do	do	South Glastonbury, 2 miles south of.
49	Andrews quarry	do	Middlesex	Rocky Hill, 4½ miles southeast of.
50	Eureka quarry	do	do	Portland, 2½ miles northeast of.
51 52	River side quarries	do	do	Middletown, east of.

TABLE 2.—*Location of the feldspar quarries, mines, and prospects, including some mica and gem mines, shown in Plates IV to VIII*—Continued.

No.	Deposit.	State.	County.	Location.
53	Consolidated quarry	Connecticut	Middlesex	Middletown, 3 miles east of.
54	Bidwell quarry	do	do	Middletown, 2½ miles south of.
55	Hallberg deposit	do	do	Middle Haddam, 2 miles southeast of.
56	Middle Haddam quarry.	do	do	Middle Haddam, 1½ miles southwest of.
57	Haddam Neck quarry.	do	do	Haddam, near.
58	Crown Point quarry	New York	Essex	Crown Point, 2 miles southwest of.
59	Barrett quarry	do	do	Ticonderoga, 1¾ miles north of.
60	Ticonderoga quarry	do	do	Ticonderoga, 1 mile southeast of.
61	Corinth quarry	do	Saratoga	Corinth, 2½ miles southwest of.
62	Batchellerville quarries.	do	do	Batchellerville, 2 miles north of.
63	Herbert Snell property	do	Hamilton	Northville (Fulton County), 4 miles north of.
64	Rhodes quarry	do	do	Northville, 3 miles northeast of.
65	Gifford prospect	do	do	Northville, 1½ miles west of
66	Tyrol Mountain quarry.	do	Fulton	Cranberry, 2½ miles west of.
67	Bedford quarry	do	Westchester	Bedford, 1 mile east of.
68	Kinkel quarry	do	do	Near and east of Bedford quarry.
69	Hobby quarry	do	do	North Castle, in.
70	Bullock quarry	do	do	½ mile west of Hobby quarry.
71	Darlington quarry	Pennsylvania	Delaware	Darlington, 1 mile northeast of.
72	Chester Heights quarry.	do	do	Chester Heights, near.
73	Bunting quarry	do	do	Chelsea, near.
74	Halsey quarry	do	do	Boothwyn, 1 mile northwest of.
75	Boothwin quarry	do	do	Boothwyn, ½ mile west of.
76	Brandywine Summit quarry.	do	do	Elam, at.
77	Old Walker quarry	do	Chester	Mendinhall, 2 miles east of.
78	New Walker quarry	do	do	About 300 yards southwest of Old Walker quarry.
79	Embreeville quarry	do	do	Embreeville, near.
80	Lafferty quarry	do	do	New Garden, 2 miles southeast of.
81	Meredith quarry	do	do	Pomeroy, 2½ miles north of.
82	Chatham quarry	do	do	Chatham, ¾ mile northeast of.
83	Jenkins quarry	do	do	Toughkenamon, 1½ miles east of.
84	Carpenter quarry	do	do	Toughkenamon, 1½ miles north of.
85	Thompson quarry	do	do	Baker, ¾ mile east of.
86	Hicks quarry	do	do	Avondale, 2 miles north of.
87	Pennsylvania quarries	do	do	Baker, near.
88	Cooper quarries	do	do	Avondale, 1½ miles southeast of.
89	Brandywine quarry	do	do	Sylmar, 1 mile north of.
90	New Brandywine quarry.	do	do	Sylmar, near.
91	Old Brandywine quarry.	do	do	Sylmar, 1½ miles northwest of.
92	Old Keystone quarry	do	do	Sylmar, west of.
93	Rock Spring quarry	Maryland	Cecil	Conowingo, 3½ miles northeast of.
94	Bald Friar quarry	do	do	Conowingo, 1½ miles north of.
95	Zepp quarry	do	Howard	Marriottsville, ½ mile south of.
96	Warfield quarry	do	do	Adjoins Zepp quarry.
97	Old Warfield quarry	do	do	Across creek from new quarry.
98	Baker quarry	do	do	Marriottsville, ½ mile east of.
99	Gifford quarry	do	Baltimore	Granite, ½ mile south of.
100	Peach quarry	do	do	Granite, 1 mile south of.
101	Cavey quarry	do	Howard	Woodstock, ¾ mile south of.
102	Dietz quarry	do	Baltimore	Davis, ½ mile east of.
103	Alberton quarry	do	Howard	Alberton, ½ mile south of.
104	Ilchester quarry	do	Baltimore	Ilchester, near.
105	McNichols quarry	Virginia	Bedford	Lowry, 5 miles south of.
106	American rutile quarry	do	Nelson	Arrington, 8 miles northwest of.
107	Prospect quarry	do	Prince Edward	Prospect, near.
108	Old Schlegel quarry	do	Amelia	Jetersville, 1½ miles northwest of.
109	Pegmatite dike	do	do	Jetersville, 2½ miles northeast of.
110	Rutherford mica mine.	do	do	Amelia, 2 miles northeast of.
111 112	Pinchback mica mines.	do	do	Amelia, 2½ miles northeast of.
113	Champion mica mine	do	do	Amelia, 3 miles northeast of.
114 115 116	Hewletts mica mines	do	Hanover	Hewletts, 2 miles southeast of.
117	Garrett property	do	Henry	Ridgeway, 2 miles south of.
118	do	do	do	One-half mile east of No. 117.
119	do	do	do	One-half mile northwest of No. 117.
120	Ridgeway mica mine	do	do	Ridgeway, ½ mile northwest of.
121	Blandford quarry	Massachusetts	Hampton	Blandford, ½ mile north of.

MAINE.

HANCOCK COUNTY.

EAST ORLAND. PEGMATITE DIKES.

Five miles northeast of Buckport, in the edge of East Orland village, Hancock County, Me., are a number of narrow pegmatite dikes (1). These dikes have withstood weathering better than the inclosing rocks and as a result protrude several feet above the land. The action of frost, however, has begun to disintegrate the feldspar and quartz particles along the lines of contact, so that low ridges of bowlders and coarse angular sand have formed, which are covered with rank growths of wild blackberries. The feldspar content of this pegmatite is a microcline with perthitic intergrowths of albite. In many places the pegmatite of these dikes contains tiny crystals of biotite so thoroughly distributed throughout the mass as to render its elimination impracticable. Other parts of the dike are reasonably free from minerals other than quartz and feldspar; this feldspar has a deformation range of 1,265° to 1,280° C.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

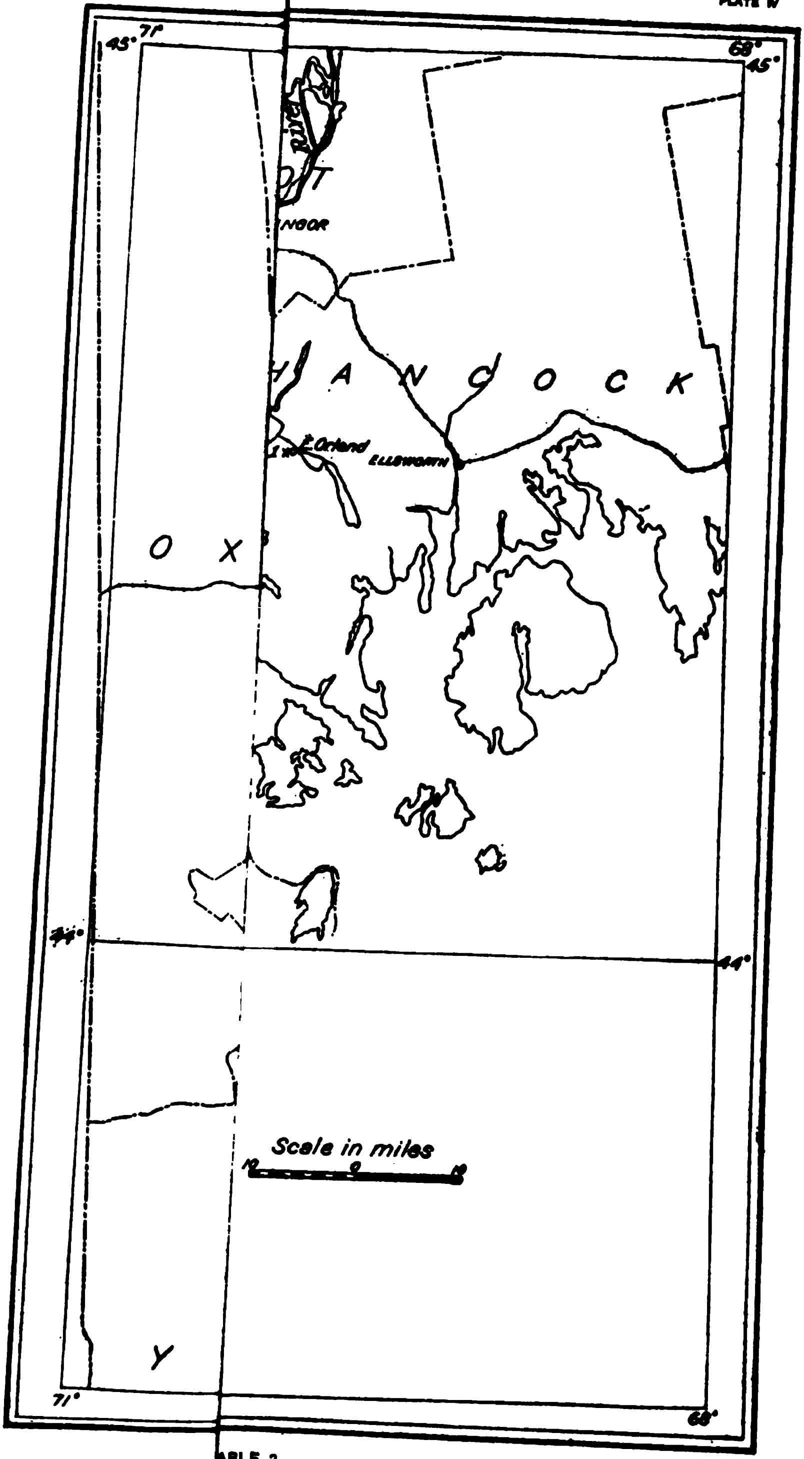
A standard porcelain mixture of this feldspar vitrifies at a temperature of 1,290° C. and shows a slight tendency to warp at 1,330° C. When fired at 1,330° it has a total shrinkage of 14.3 per cent, a cream tint by transmitted light, and a translucency of 0.660. The color is equal to that of the standard trial and is unaltered both under the raw-lead and the fritted glazes.

LINCOLN COUNTY.

NEW CASTLE. JOHN GLIDDEN PROPERTY.

The John Glidden property is 2 miles west of New Castle village. This deposit (2) is a dike that varies in width up to about 60 feet and is of varying quality as regards the occurrence of biotite and garnet. The garnet, however, is present in such quantity as to seriously injure the feldspar for pottery purposes. The dike strikes northeast, the dip varies from 80° West to 75° East. The west side of the dike is exposed, forming the face of a cliff 30 feet high, at the base of which a small stream runs south to tidewater, a distance of 1 mile. The Maine Central Railroad is 1½ miles south.

The developments consist of a few surface prospect pits which have been poorly placed and furnish little information as to the real structure of the dike. There is no overburden along an exposure of about 1,200 feet. The better parts of the dike where exposed were sampled and the average has the following chemical composition.


71°
45°
68°
45°
NGOR
H A N C O C K
Orland
ELLSWORTH
O X
44°
44°
Scale in miles
10
0
10
Y
71°
68°

ABLE 2.

Composition of high-grade feldspar from Glidden property.

SiO_2	64.67
Al_2O_3	19.18
Fe_2O_3	0.20
CaO	0.99
MgO	Trace.
Na_2O	2.54
K_2O	12.76
	100.34

The analysis indicates a fairly fusible composition and the color when fused is above criticism as is the case with practically all of the Maine feldspars when properly cleaned of their associated ferromagnesium impurities. This feldspar deforms between 1,270° and 1,285° C., being slightly more fusible than Seger cone 8, it does not, however, become distorted in the early stages of fusion as might be expected from its calcium content. It fuses to an opaque white glass.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

A standard mixture of this feldspar vitrifies at 1,270° C. and shows slight warpage at 1,330° C. The color is equal to that of the standard trial. Fired at 1,330° the product has a total shrinkage of 14.6 per cent, a cream-white tint, and a translucency of 0.615. Under the raw-lead and fritted glazes the color is unaltered.

EDGECOMB. ABANDONED QUARRY.

There is an old abandoned quarry (3) at Edgecomb, 2½ miles from the New Castle Township line and 4½ miles southeast of Wiscasset.

This deposit[a] contains considerable impure pegmatite, due to the contamination of small biotite crystals, but also contains considerable commercial pegmatite, which is exposed in a well-defined part of the dike, 25 to 50 feet wide, and cleared of overburden for a distance of 100 feet. The same dike is exposed at various places of uncertain width for a distance of about 500 feet north. The dike is almost vertical. At the time of visiting an opening about 25 feet deep had been made for the recovery of mica of the muscovite variety, which occurs throughout the dike. The pegmatite contains small lenses of massive white quartz and some beryl in the parts rich in feldspar. The feldspar in the part of this dike not seriously contaminated with biotite mica was sampled and found to be of a very good quality but of a rather soft type, its deformation range being from 1,255° to 1,260° C. It fuses to an enamel-like glass and entirely loses its shape at 1,270° C.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, 1910, pp. 27 and 28.

PROPERTIES IN THE STANDARD PORCELAIN MIXTURE.

The standard porcelain mixture of this feldspar vitrifies at 1,260° C. and shows warping at 1,290° C. Its color is hardly equal to that of the standard trial. Fired at 1,290° C. it has a cream tint by transmitted light and a translucency of 0.667, and a total shrinkage of 14.6 per cent. The color is unaltered under either raw-lead or fritted glaze.

EDGECOMB. HULL PROPERTY.

The Hull property (4) is on the east side of Sheepscot River, 4 miles south of Wiscasset, in the town of Edgecomb. This dike follows a ridge along the east side of the river, its height varying from sea level at high tide to 200 feet above sea level. The pegmatite does not seem to be so clean at the higher points but the material exposed there may be capping. Pegmatite of excellent quality is exposed at a number of places, but no development work has been done, and hence no estimate of quantity or uniformity can be made.

Samples of the clean pegmatite have a deformation range of 1,275° to 1,290° C. and fuse to a semitransparent mass free from color.

SAGADAHOC COUNTY.

GEORGETOWN. NOBLE AND SMITH PROSPECTS.

On Georgetown Peninsula, due east of the Golding quarry, is a dike of pegmatite, which may be traced over a considerable distance. Two openings (5 and 6) have been made, but no feldspar has been shipped. The feldspar exposed is microcline pegmatite with a small content of impurity, chiefly biotite.

Samples of the feldspar show a deformation range of 1,278° to 1,290° C. and fuse to a translucent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard porcelain mixture of this feldspar vitrifies at 1,280° and at 1,330° shows no warpage. Fired at 1,330° C. it has a total shrinkage of 14.3 per cent, a cream color by transmitted light, and a translucency of 0.640. The color is unaltered under the raw-lead and fritted glazes.

CATHANCE. ALFRED GRAVES QUARRY.

The Alfred Graves quarry (7) 2 miles north of Cathance station. At the time of inspection this property had been opened by a pit about 30 feet wide, 40 feet long, and 10 to 15 feet deep. A dike of varying width is exposed in places for at least 100 feet along the strike northwest and southeast of the pit. The dike reaches a maximum width of 70 feet in some places, but from surface indications its quality varies greatly. The overburden varies from one-half to 3 feet in thickness. Biotite occurs in considerable quantity in some parts of the dike, but in other parts is almost entirely absent. Beryl is present locally, but not in sufficient quantity to constitute a menace. About 500 tons of commercial pegmatite has been mined and shipped from this property, which shows indications of much more feldspar of pottery grade. The deposit lies nearly flat, and a band of coarse, impure granite, encountered at a depth of 10 to 15 feet, is reported as continuing through to the other side of the sill, but no prospect holes or other evidence is available to substantiate this claim.

Samples of this feldspar show a deformation range of 1,265° to 1,280° C. and fuse to a semitransparent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the feldspar produces vitrification at 1,280° C. and at 1,330° C. shows no warpage. The color is the same as that of the standard trial. Fired at 1,330° C. the mixture has a total shrinkage of 14.3 per cent, is cream white by transmitted light, and has a translucency of 0.645. The color is unaltered under the raw-lead and fritted glazes.

CATHANCE. MAINE FELDSPAR QUARRY.

The Maine quarry (8) is 2 miles north of Cathance station, on property adjoining on the south of the Alfred Graves property. This deposit is probably a continuation of the dike opened at the Graves quarry but dips more than on the Graves property. This dike varies widely in its structure, and much material high in impurity must be handled in the removal of the merchantable pegmatite. The dike dips under a ridge and the increase in thickness of overburden which must be removed has prevented very deep quarrying. The pegmatite part of the dike averages about 12 feet in width. The feldspar has a deformation range of 1,265° to 1,280° C. and fuses to a semitransparent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar produces vitrification at 1,280° and no warping is evident at 1,330° C. Fired at 1,330° C., the total shrinkage is 14.0 per cent, the color by transmitted light is cream white, and the translucency is 0.650. The color is unaltered under the raw-lead and fritted glazes.

CATHANCE. MAINE GRAPHIC GRANITE QUARRY.

This deposit (9) is 2½ miles northwest of Cathance and is part of the dike worked at the large Trenton quarry one-half mile north. At the time of visiting a face 60 feet wide and 60 feet high, worked in two benches, was exposed. The material exposed is a good grade of graphic granite, but contains both black and white mica, and all of it has to be cobbed or sorted before it is sent to the mill. The quality of the feldspar is practically the same as that of the potash feldspar being mined at the Trenton quarry, although the structure of the dike at this north exposure is more irregular and requires more careful mining than seems to have been necessary in working the older and larger opening.

A sample of the feldspar of this dike had a deformation range of 1,265° to 1,280° C. The fused product is a semitransparent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

A standard mixture of the feldspar vitrifies at 1,270° and warps slightly at 1,330° C. The total shrinkage when fired at 1,330° is 14 per cent. The color is cream white, and the translucency is 0.635. The color is not altered by the application of either the raw-lead or the fritted glazes.

CATHANCE. TRENTON QUARRY.

The Trenton quarry[a] (10), 2 miles northwest of Cathance, is one of the oldest feldspar operations in Maine and represents the largest production in the New England States. The quarry, which is about three-fourths mile west of the highway, consists of a series of open cuts ranging from 15 to 60 feet in height of face exposed and in some places is 200 feet wide. This deposit has been worked out for a distance of 200 yards and the indications are that it continues for a considerable distance to the north, which is the direction of the strike of the dike. The deposit mined has consisted chiefly of a rich graphic granite and coarse pegmatite, with numerous lenses of sugar quartz and pure feldspar that in some places is potash feldspar and in other places soda feldspar. The soda feldspar is more or less broken by weathering, presenting a chalky appearance, but the potash feldspar seems to be still unweathered.

Samples of the potash feldspar were tested and showed a deformation range of 1,265° to 1,280° C. The color is an excellent white and the standard porcelain body in which this material is used shows a shrinkage of 14.6 per cent and a translucency of 0.667.

The soda feldspar deforms only at a very high temperature, owing to the fact that the weathering has removed some of the alkali, leaving a residue of semikaolinized material. This soda feldspar has never been used by the operating company as a commercial product, but a test of this material in porcelain bodies shows that it has a shrinkage of 13.4 per cent and a translucency of 0.620, which indicates that it would be valuable fluxing material for many purposes.

CATHANCE. OLD W. G. WILLIS QUARRY.

The W. G. Willis quarry[b] (11) is 1 mile west of Cathance. This property is south of the Trenton quarry and is apparently a continuation of this same dike or at least consists of stringers from this dike. The mass is not so uniform as the main dike, but contains many large lenses of pure potash feldspar, the rest of it being an excellent grade of graphic granite. The opening of this quarry is in the center of a large flat plateau, and at the time of the writer's visit the quarry was filled with water to a considerable depth, making a satisfactory examination of this deposit impossible. The difficulty of operation has prevented this property being worked recently, but the feldspar mined was regarded as of excellent quality and was all bought and used by a local company.

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[a] See Bastin, E. S., Economic geology of the feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, 1910, pp. 38-39.

[b] Bastin, E. S., Op. cit., pp. 37-38.

The results of an analysis of a sample of this feldspar are as follows:

Results of analysis of potash feldspar from W. G. Willis quarry.

	Per cent.
Ignition loss	0.33
SiO_2	73.89
Al_2O_3	14.33
Fe_2O_3	.16
TiO_2	
CaO	Trace.
MgO	Trace.
BaO	
K_2O	9.2
Na_2O	2.14
Total	99.87

CATHANCE. OLD GOLDING QUARRY.

The old Golding quarry (12) is 1 mile west of Cathance station and adjoins the old W. G. Willis quarry on the south. This property was worked in former years when only the pure feldspar was removed, and hence much high-grade graphic granite is left and also many small dikes, which were formerly considered too small to justify quarrying. The structure and the strike of the deposit indicates that it is a continuation of the dike worked at the Maine, Trenton, and W. G. Willis quarries.

CATHANCE. NEW W. G. WILLIS QUARRY.

The new W. G. Willis quarry (13) is located on the same dike as the Trenton quarry, the old Golding quarry, and the old W. G. Willis quarry, and is due south from them. This quarry has the advantage of being near the southern slope of the hill, and hence the problem of drainage, which is the great handicap in the old W. G. Willis quarry, is not encountered here. The dike here, like all other exposures on this strike, varies widely but contains much pure feldspar and also much high-grade pegmatite and graphic granite. The muscovite, biotite, and beryl present in this part of the dike are all so coarsely crystalline that they can be easily eliminated by rough cobbing during mining. This quarry had not extended to any considerable depth at the time of inspection, but as the dike is nearly vertical it will doubtless produce much high-grade pottery feldspar. Samples of this feldspar have a deformation range of 1,275° to 1,290° C. and fuses to a translucent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

A standard mixture of this feldspar vitrifies at 1,280° C. and warps slightly at 1,330° C. Fired at 1,330° C., this mixture has a total shrinkage of 13.8 per cent, a cream-white tint, and a translucency of 0.660. Under the raw-lead and fritted glazes the color of the body is unaltered.

CATHANCE. OLD FISHER QUARRY.

The old Fisher feldspar quarry[a] (14) is directly south of the W. G. Willis quarry. This property has been reopened and a considerable quantity of excellent feldspar mined. The dike is similar to others in this district and consists of a graphic granite of medium to fine grain and many lenses of pure feldspar. Considerable beryl and muscovite is found in certain parts of this dike, but biotite seems to be present only in small quantity.

The graphic granite of this deposit was sampled and analyzed. The results of the analysis are as follows:

Composition of graphic granite from old Fisher quarry.

	Per cent.
SiO_2	74.34
Al_2O_3	14.45
Fe_2O_3	.16
CaO	Trace.
MgO	Trace.
Na_2O	2.00
K_2O	8.63
	99.56

The composition of the feldspar content of the graphic granite was as follows:

Composition of feldspar content of graphic granite.

	Per cent.
SiO_2	65.07
Al_2O_3	19.39
CaO	Trace.
MgO	Trace.
Fe_2O_3	.10
K_2O	12.58
Na_2O	2.52
	99.66

The pure feldspar has a deformation range of 1,275° to 1,290° C. and fuses to a semitransparent mass free from tint.

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[a] See Bastin, E. S., Op. cit., pp. 36-37.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard mixture of this feldspar vitrifies at 1,280° and warps slightly at 1,330° C. The color is equal to that of the standard trial. Fired at 1,330° C., the mass has a total shrinkage of 13.8 per cent, a cream-white tint, and a translucency of 0.683. The color is unaltered under the raw-lead and fritted glazes.

TOPSHAM. MAINE FELDSPAR CO. DEPOSIT.

The Maine feldspar deposit (15) is 2 miles east of Topsham. This property, which was opened during the summer of 1912, lies along a ridge running northeast. The dike varies from 80 to 100 feet in width and is exposed for a distance of about 750 feet. The deposit dips about 70° west, but is so folded that the continuation of this dip with depth is uncertain. The dike material consists of a graphic granite or pegmatite of varying coarseness and contains numerous lenses of material very rich in biotite, which is in the form of large lath-like crystals, having a maximum length of 1½ feet and a width of 3 inches. At the time of visiting, the dike had only been exposed to a depth of about 10 feet along the south face, but at the north end of the property an exposure about 30 feet high had been made which showed a reasonably uniform grade of graphic granite of a buff color.

This material was carefully sampled and was found on testing to be a good average feldspar, having a deformation range of 1,270° C. to 1,285° C. Samples of the pure feldspar lens in this dike were tested and found to have a deformation range of 1,260° C. to 1,270° C., which indicates that this pure feldspar is much more fusible than the graphic granite and should be valuable for softening the other material, which is naturally more or less refractory owing to the quartz content of the graphic granite.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The graphic granite, when made into a standard porcelain body, shows a shrinkage of 14 per cent, a cream-white tint, and a translucency of 0.635. The pure feldspar, when made into a standard porcelain body, shows a shrinkage of 13.4 per cent and a cream translucency of 0.707. Under the raw lead and fritted glazes the color is unaltered.

TOPSHAM. MOUNT ARARAT QUARRIES.

About 1 mile north of Topsham village, on Mount Ararat, are numerous dikes of pegmatite, which have been worked at different times for feldspar.[a] None of these dikes are large but the structure is so folded that most of the work has consisted of removing the high-grade pegmatite exposed on the surface.

At the time of visiting there was a large, shallow pit about 150 feet long and 30 feet wide on the north slope of the hill and the deposit had apparently been worked out.

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[a] For a description of these deposits see Bastin, E. S., Economic geology of the feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, 1910, pp. 34-36.

A quarry (16) has been opened on the west slope of Mount Ararat and follows the slope for a distance of about 50 feet. The dike structure here is much folded, and many bands of gneiss are inclosed in the deposit, so that only about 40 per cent of the dike material is pegmatite. This deposit produced only a small amount of merchantable feldspar and has been abandoned as a source of high-grade material, being used recently as a quarry for the production of road material, which is crushed near the quarry and used on the neighboring highways.

On the south slope of the hill a quarry (17) about 30 feet long by 20 feet wide has been opened. This deposit is a mixture of microcline and albite pegmatite, and contains very little biotite and garnet, which is generally very prevalent in the pegmatite of this district. This quarry has been worked to a depth of about 20 feet and the walls and floor indicate that good pegmatite still remains in this pit, although the deposit is much folded. The wall rock, which is a schist, does not intrude into the dike at this point. Very few masses of pure feldspar are exposed but the pegmatite, where not contaminated by iron-bearing minerals, is of a good pottery grade.

This feldspar deforms at 1,260° C. to 1,270° C., and fuses to an enamel-like semiopaque pure white mass.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard porcelain mixture of this feldspar vitrifies at 1,270° C., and at 1,330° C., slight warpage is evident. The color is similar to that of the standard trial. After firing at 1,330° C. the total shrinkage is 13.8 per cent, and the translucency is 0.670 and the color cream white.

BATH. DAUPHIN PROPERTY.

On a hill one-half mile west of High Street, Bath, are two ledges of pegmatite, which are apparently of a quality to produce commercial pottery feldspar. The ledges are dikes which project about 25 feet above the ground, and on their exposed surfaces show a fair grade of pegmatite with many small masses of pure feldspar of a buff color. No prospecting has been done and the surface material is so badly stained from the thin overburden of soil that no reliable report was possible on this deposit.

TOPSHAM. NOYES PROPERTY.

In the west end of the village of Topsham, on the main street and 1 mile west of the post office, is a pegmatite dike. The surface pegmatite is of good quality but at the time of visiting no development had been attempted and little could be determined from the exposure, which was about 30 by 125 feet and about 50 feet from the highway. The feldspar is buff colored where exposed, and the pegmatite seems to be very low in quartz content. Biotite, garnets, and magnetite are noted, but are not abundant and are confined to limited areas. Massive quartz and feldspar are also present. This dike is in the center of a level area, and a brook which runs along the east wall of the dike would have to be diverted into a new and lower channel or pumping resorted to if the deposit were to be mined.

RIGGSVILLE. MASON DEPOSIT.

The Mason property (18) is on Georgetown Peninsula, near the town of Riggsville. Deposits of feldspar are exposed over a large area and as ledges above Back River, which is tidewater. The dikes strike in all directions from northeast to southeast, and the dip varies from 45° to 90°. The deposits have been developed only by a few poorly placed shots, and little real information regarding the structure of the dikes below the surface is available. The presence of considerable garnet was noted, and lenses of pure feldspar at frequent intervals. These lenses were sampled and found to be of fair quality.

The feldspar present is a microcline with minute intergrowths of albite. It has a deformation range of 1,275° to 1,290° C. and fuses to a semitransparent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard mixture of this feldspar vitrifies at 1,280° C. and warps slightly at 1,330° C. The color is equal to that of the standard trial. Fired at 1,330° C. it has a cream-white tint, a translucency of 0.643, and a total shrinkage of 13.9 per cent. Under the raw-lead and fritted glazes no change in color occurs.

RIGGSVILLE. NOBLE DEPOSIT.

The Noble deposit (19) is on Georgetown Peninsula, due southeast of the Mason deposit, and consists of at least four stringers, which strike northwest to southeast across a ridge. The material of the dikes is of varying quality, but seems to consist of a fair quality of feldspar in some places, grading into a fine-grained pegmatite in other places. The lack of any but surface exposures prevented a more thorough investigation of this deposit. Where pure masses of feldspar occur it resembles the pure feldspar of the Mason deposit and has the same range of deformation.

GEORGETOWN. GOLDING QUARRY.

The Golding quarry (20) is on Georgetown Peninsula. The deposit has been described by Bastin.[a]

At the time the writer visited this property the last opening and the one being operated consisted of an open cut about 50 feet wide and directly below the original opening. The new cut is made from the face of the hill and thus affords natural drainage, obviating the necessity of siphoning, which was required in the old opening. A lens of pure feldspar about 20 by 50 feet in size lies directly to the east of this cut. The greater part of this lens had been removed and utilized to raise the feldspar content of the output from the main deposit, which consists chiefly of a pegmatite or graphic granite. This graphic granite was sampled and analyzed. The results of the analysis are as follows:

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[a] Bastin, E. S., Economic geology of the feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, 1910, pp. 31, 32, and 33.

Composition of graphic granite from Golding quarry.

	Per cent.
SiO_2	74.53
Al_2O_3	14.26
Fe_2O_3	.16
CaO	Trace.
MgO	Trace.
Na_2O	2.25
K_2O	8.55
	99.75
Combined H_2O	.30

This deposit contains very little mica, either in the form of muscovite or biotite, the chief impurity being sharply defined crystals of black tourmaline (schorl), which is separated by cobbing from the rest of the dike material. The product as marketed is of good quality, but being graphic granite necessarily contains some free quartz.

At this quarry the face was mined in benches 2½ to 3 feet wide and 5 feet high. The holes are made with steam drills and loaded with 40 per cent dynamite, the shots being fired at noon and night after the workmen have left the quarry. The loosened material is removed from the quarry in tramcars. which run on a track and are drawn by horses.

The quarry is situated directly on tidewater and the feldspar is loaded into scows and conveyed to Bath, Me., and there reloaded for shipment to the western pottery centers, or is shipped directly from the quarry wharf by barge to Trenton, N. J.

This material begins to deform at about 1,270° C. and is completely deformed at 1,285° C., but at 1,290° shows no evidence of becoming a fluid glass. The fused feldspar is free from tint and is semitransparent.

PROPERTIES IN THE STANDARD PORCELAIN MIXTURE.

The standard porcelain mixture made with this feldspar vitrifies at 1,280° C., and at 1,330° C. shows no warpage. The color is equal to that of the standard trial. When fired at 1,330° C. the total shrinkage is 14 per cent, the color cream white, and the translucency 0.670. Under the raw-lead and fritted glazes the color is unaltered.

PHIPPSBURG. JOSEPH B. PERRY PROPERTY.

The Joseph B. Perry property (21) is adjacent to and 50 to 80 feet above tidewater at Phippsburg Basin, town of Phippsburg. This feldspar deposit is a well-defined dike, which varies in width from 6 to 15 feet and strikes northwest to southeast. The deposit is almost vertical and has been opened to a depth of 10 to 20 feet. The original work was done on this property in 1878 and about 350 tons of feldspar were shipped. Toward the west end this dike contains intrusive lenses of pure quartz and toward the east end the pegmatite, of which the dike principally consists, is replaced by pure feldspar lenses of considerable size. Large crystals of muscovite occur along the walls, but this muscovite is mostly of grinding quality only. The lenses of pure feldspar appear to be of very uniform quality and were sampled; an average of the samples showing the following chemical composition:

Composition of pure feldspar from Perry property.

	Per cent.
SiO_2	64.90
Al_2O_3	19.75
Fe_2O_3	.12
CaO	None.
MgO	Trace.
Na_2O	2.68
K_2O	12.04
	99.49
Combined H_2O	.25

This feldspar deforms between 1,265° and 1,280° C. and has an excellent color. When fused at 1,290° the product is a semitransparent glass.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard mixture of the feldspar vitrifies at 1,270° C., and at 1,330° C. shows no warpage. The color is equal to that of the standard trial. Fired at 1,330° C. the feldspar is cream white, the translucency is 0.637, and the total shrinkage is 14.7 per cent. The color is unaltered under either the raw-lead or the fritted glaze.

CUMBERLAND COUNTY.

SOUTH FREEPORT. STAPLE POINT DEPOSIT.

There is a feldspar deposit (25) on Staple Point, a short peninsula on the coast just west of South Freeport, Cumberland County, Me.

Dikes 6 to 15 feet wide containing much pure feldspar extend along the ridge of this peninsula for a distance of 700 or 800 feet in a westerly direction. The land lies from 30 to 50 feet above tidewater, but many exposures of promising quality are noted below tide level. Along the coast at this point the water is not deep enough for schooners to enter, but scows could be loaded directly from the deposit or the material could be hauled by wagon to South Freeport and from there shipped by rail to any desired point.

The surface material consists of both feldspar and pegmatite; no openings have been made of sufficient size to indicate the quality of the lower part of the deposit. There is no overburden except a few inches of soil or loam, and the deposit could easily be thoroughly tested by a few well-placed holes. If the inconvenience of tidewater operations can be overcome there is every evidence that this deposit should produce some excellent feldspar.

The feldspar of this deposit was carefully sampled and tested, and the results show that the deforming temperature lies between 1,255° and 1,270° C.

PROPERTIES IN THE STANDARD PORCELAIN MIXTURE.

Made into a standard porcelain body the feldspar shows a translucency of 0.663 and has a shrinkage of 13.4 per cent. The color when fused is an excellent white.

AUBURN. CHARLES SAWYER DEPOSIT.

The Charles Sawyer deposit (41), at Rumford Junction, 4 miles west of Auburn, is a dike consisting of a number of separate bands that vary from 2 to 20 feet in width and differ widely in structure. A highway lies between the railroad and the exposure, which is on the east slope of a hill and rises to a maximum height of 130 feet above the railroad. On the lower parts of this slope a number of lenses, showing a fair quality of pegmatite and numerous lenses of pure feldspar, are well exposed. The banded part of this dike which is exposed at higher levels has a more granitelike structure, and where the micas and garnet occur as impurities is too fine grained to be cleaned.

The better parts of this deposit were sampled and found to have an excellent color and a deformation range of 1,270° to 1,285° C.

The feldspar fuses to a semitransparent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard mixture of this feldspar vitrifies at 1,280° C. and warps slightly at 1,330° C. Its color is equal to that of the standard trial. Fired at 1,330° C. the total shrinkage is 14.1 per cent, the translucency is 0.667, and the color by transmitted light is cream white. The color is not altered by the raw lead and fritted glazes.

AUBURN. DOW PROPERTY.

The Dow property (42) is at Rumford Junction, 4 miles west of Auburn, on an elevation due west of the Sawyer property. A dike of pegmatite of variable quality is exposed on a ridge running north and south. At the time of visiting no development work had been done, but numerous lenses of pure feldspar are exposed and masses of pegmatite free from impurity are numerous also. The major part of the dike, which can be traced for about 300 yards, is a fine-grained pegmatite with much biotite and some small garnets exposed on the surfaces. This property would justify more thorough prospecting.

OXFORD COUNTY.

DIXFIELD. OLD KNOX QUARRY.

The old Knox quarry (26) is 3½ miles southwest of Dixfield, where a large dike of pegmatite of varying quality outcrops on the southwest face of a steep cliff. It has been worked at various times for mica, of which only a limited amount of marketable material has been obtained. The exposure is from 20 to 40 feet wide. Along the abrupt slope of the hill occasional lenses of pure feldspar may be observed, but the fact that biotite is distributed throughout most of the exposed face indicates that this material would require hand sorting to make it marketable feldspar. Also small garnets are scattered through a considerable part of the exposed face and would tend to reduce the commercial value of the product somewhat, although they probably would not cause it to be rejected.

Samples of the pegmatite and pure feldspar were taken in the proportions in which they are estimated to occur and these samples were tested with the following results: Deformation range, from 1,270° to 1,285° C.; color, good; shrinkage of standard porcelain body, 14.2 per cent; translucency, 0.597.

SOUTH PARIS. MOUNT MICA DEPOSITS.

There are deposits of feldspar (27) on the crest of Mount Mica, 5 miles northeast of South Paris. Mount Mica consists of a ridge with one pronounced knoll, which appears to be the center of an area very rich in gem materials. The dike has a general east and west trend and dips slightly southwest. The structure of this dike is exceedingly variable and does not seem to be banded, but is rather a mass of associated lenses of widely varying composition. Numerous lenses of massive feldspar are encountered and also many lenses of both graphic and irregular pegmatite. Muscovite and black tourmaline are common, but there is very little garnet evident. Lithia mica (lepidolite) is scattered throughout the deposit and its presence is considered to indicate a gem pocket. Both the pegmatite and the massive feldspar are of sufficient quality to justify their use as ceramic materials, the distance from a railroad being the chief drawback to their use. Hand sorting would be necessary to insure the elimination of the undesirable associated material, but would undoubtedly be profitable.

Samples of the feldspar from this deposit show a deformation temperature of 1,260° to 1,265° C., and 10° more converts the material into a glass of enamel-like opacity but lacking the complete fusion indicated in most high-soda feldspars.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture the product has a shrinkage of 14.4 per cent and a translucency of 0.647. The translucency is high for a porcelain containing the proportion of soda feldspar which the deformation action seems to indicate.

OWLS HEAD. BUCKFIELD DISTRICT.

The Buckfield district (28) is north of Owls Head and east of Streaked Mountains. It consists of a low ridge with numerous small dikes of pegmatite, all having an east and west trend. Some are quite free from impurities and others are so impure as to be valueless. The impure ones, contain, however, practically every rare gem and mineral found in Maine. The purer deposits of feldspar and pegmatite have not been opened as prospecting through this district has been confined heretofore to searches for gem minerals, and the dikes containing pure feldspar are in most cases exposed only by the removal of the overburden. The feldspar and pegmatite seem to be uniform in quality and in several places extend continuously for about 100 feet. The fact that no openings had been made in this clean rock prevented a satisfactory sample being taken by the writer, but the indications point to the presence of good commercial material in this district.

SOUTH PARIS. HOOKER RIDGE.

On Hooker Ridge, 1½ miles east of South Paris, a pegmatite dike (29) is exposed on the west slope of an abrupt hill and has a general strike north and south which permits its being easily quarried. At the time of visiting the exposure was about 250 feet long and 40 feet high. The bands adjoining the hanging wall, which is on the east, are full of biotite and can not be sufficiently refined for ceramic uses. The west half of the dike, which varies in thickness from 10 to 30 feet, is a mixture of massive feldspar and pegmatite with the impurities in isolated lenses, which would permit their removal by hand cobbing and sorting. The impurities in this part of the dike consist chiefly of black tourmaline and muscovite, also numerous lenses of a fine quality of rose quartz are encountered. About 25 to 30 per cent of this dike could be made marketable material.

The marketable material was carefully sampled and found to have a deformation range of 1,275° to 1,290° C. When fused it becomes semitransparent and is free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280°, and at 1,330° C. shows no warpage. The color is equal to that of the standard trial. Fired at 1,330° C. the total shrinkage is 13.8 per cent, the translucency is 0.657, and the color cream-white.

HEBRON. NO. 4 HILL QUARRY.

The No. 4 Hill quarry (30) is on the south slope of No. 4 Hill in the town of Hebron.[a]

This quarry is opened in a dike of coarsely crystalline pegmatite, many masses of pure feldspar being exposed both on the surface of the dike and on the walls and floor of the quarry. The feldspar constituent of the pegmatite is chiefly microcline, a small amount of albite occurring as clevelandite in small pockets scattered through the dike. Biotite is almost entirely absent, the chief iron-bearing mineral in the pegmatite being black tourmaline. This mineral does not occur in isolated masses as is the case in most dikes where it is found, but is scattered as small crystals throughout the extent of the dike so far as exposed. Careful cobbing will be required to eliminate it from the feldspar. The lenses of feldspar free from quartz are also comparatively free from tourmaline, hence this part of the dike may be made use of. The proportion of the deposit which would be marketable is not great enough to make quarrying very profitable. Muscovite (white mica) is scattered in "books" through the dike, but is ruled, and hence would not be valuable except for grinding. Samples of the pure feldspar show a deformation range of 1,270° to 1,290° C. and fuse to an almost transparent glass.

PROPERTIES IN THE STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280° C. and at 1,330° C. shows no warpage. The color is equal to that of the standard trial.

Fired at 1,330° C. the total shrinkage is 14.2 per cent and the translucency is 0.647 and the color cream-white. The color is not altered by either raw-lead or fritted glaze.

HEBRON. HIBBS QUARRY.

The Hibbs quarry[b] (31) is 1 mile north of Hebron Academy in the town of Hebron and 3 miles west of East Hebron Station. This deposit is situated in a level tract in the heart of an elevated area of considerable extent and a stream passes directly over the deposit, exposing it in many places.

The dike is distinctly banded, several of the bands being practically pure feldspar and others high-grade pegmatite. The dike strikes almost north and south and dips 45° west. Along the hanging wall large blocks of excellent muscovite were exposed at the surface or in the bottom of shallow shot holes which had been drilled there. A width of 12 to 15 feet of this dike could be profitably quarried for its feldspar and should yield an excellent material, judging from the results of the tests and analysis. The feldspar had the following composition:

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[a] See Bastin, E. S., Economic geology of the feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, 1910, pp. 29-30.

[b] See Bastin, E. S., Op. cit., pp. 28-29.

Composition of feldspar from Hibbs quarry.

	Per cent.
SiO_2	65.48
Al_2O_3	19.39
Fe_2O_3	.08
CaO	None.
MgO	Trace.
Na_2O	2.85
K_2O	11.51
	99.31

The feldspar has a deformation range of 1,260° to 1,280° C. and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

A standard mixture of this feldspar vitrifies at 1,280° C. and warps slightly at 1,330° C.; the color is equal to that of the standard trial. The total shrinkage at 1,330° C. is 15 per cent, the translucency is 0.680 and the color is cream-white.

PARIS HILL. MOUNT RUBELLITE DEPOSIT.

The Mount Rubellite deposit (32) is north of Paris Hill post office. This deposit is not extensive and resembles in many ways the Mount Mica deposit. The dike contains practically all the minerals found at Mount Mica, the major part of it consisting of an irregular mass of feldspar and coarse pegmatite. This was sampled and tested and found to have a deformation range of 1,265° to 1,280° C. In the standard porcelain body the material showed a shrinkage of 14.2 per cent and a translucency of 0.675.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

This feldspar in the standard porcelain mixture vitrifies at 1,280° and does not warp at 1,330° C. The color is similar to that of the standard trial. Fired at 1,330° C. the total shrinkage is 14 per cent, the translucency is 0.660, and the color by transmitted light is cream white. The application of raw lead and fritted glazes does not affect the color of the porcelain.

NORWAY. STEVENS LEDGE.

Stevens Ledge (43) is 2 miles northeast of Norway, and consists of a dike exposed for a considerable distance across a ridge. Another dike, or a stringer of the same dike, of less width but greater purity, adjoins this chief deposit on the west. The general strike of both dikes is north and south and the dip is practically vertical. The larger dike forms a ridge, owing to the weathering away of the rock in which it is intruded, about 15 feet high. The pegmatite contains muscovite and biotite in small quantity, but disseminated throughout the mass, and also some small garnets. The smaller dike to the west contains very coarse pegmatite and massive feldspar, and has been opened to a depth of about 10 feet. Its chief impurity is black tourmaline, which is present only in coarse aggregate. A short distance to the west of these two dikes, ledges of quartz about 6 feet wide outcrop on the hill slope, which indicates the occurrence of other dikes striking at right angles to the two chief pegmatite deposits.

The feldspar from the smaller dike was sampled and analyzed, the composition being as follows:

Composition of feldspar from Stevens Ledge.

	Per cent.
SiO_2	64.97
Al_2O_3	19.48
Fe_2O_3	.04
CaO	None.
MgO	Trace.
Na_2O	2.56
K_2O	11.76
	98.81
Combined H_2O	.125

This feldspar had a deformation range of 1,270° to 1,285° C. In the standard porcelain mixture it has a shrinkage of 14 per cent and a translucency of 0.630.

ANDROSCOGGIN COUNTY.

AUBURN. PEGMATITE DIKE.

In the Hillcrest section of South Auburn a feldspar deposit (22, 23, 24) extends along a range of hills 1½ miles south of Auburn, between the old Danville road and the Mill road, and outcrops on a number of properties. The dike has an irregular formation and has a general north and south trend, but gives off many stringers at widely different angles. Trap-rock dikes cut this pegmatite dike at many points. The chief impurities associated with the pegmatite are black tourmaline, small garnets, and mica. The major part of the dike consists of a coarse pegmatite which could be rendered commercially pure by reasonable care in hand sorting. No attempt has been made to develop this deposit, and the dike structure where exposed by the few openings made varied so widely that the possibilities of the deposit could not be estimated. The better part of the dike was sampled. The results of the chemical analysis of this sample are as follows.

Composition of better grade of feldspar.

	Per cent.
SiO_2	67.81
Al_2O_3	18.55
Fe_2O_3	.08
CaO	.21
MgO	.07
Na_2O	4.27
K_2O	9.32
	100.31

This material has a deformation range of 1,270° to 1,285° C. and has an excellent color.

PROPERTIES IN THE STANDARD PORCELAIN MIXTURE.

The standard mixture of this feldspar vitrifies at 1,280° C. and at 1,330° C. shows no warping. The color is good, but hardly equal to that of the standard trial, which may be due to the fact that the samples were surface stained. Fired at 1,330° C. the standard mixture has a total shrinkage of 15 per cent, a translucency of 0.637, and is cream-white.

MOUNT APATITE. PULSOPHER DEPOSIT.

The Pulsopher deposit (33) is on the west slope of Mount Apatite and about one-fourth mile northwest of the other workings on that slope. The deposit consists of a large lens of soda feldspar, which has been worked exclusively for gem materials. This feldspar has never been tested for ceramic uses and the extent of the workings does not indicate that the amount of material here is very great, but the quality and color are both excellent and are characteristic of the best soda feldspar. An average of the samples taken had the following chemical composition:

Composition of soda feldspar from Pulsopher deposit.

	Per cent.
SiO_2	66.36
Al_2O_3	21.35
Fe_2O_3	0.12
CaO	1.10
MgO	0.21
Na_2O	9.74
K_2O	0.73
	99.61
Combined H_2O	.16

This feldspar has a deformation range of 1,265° to 1,270° C. and at 1,275° fuses to an opaque glass.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

This feldspar produces vitrification at 1,270° but the porcelain has a dull surface and lacks the metallic ring characteristic of porcelain of the potash variety. The color is excellent, but the surface texture is so different that it can not be compared with the standard trial. The total shrinkage when fired at 1,330° C. is 12.8 per cent, the translucency is 0.570, and the color is cream. Under the raw-lead and fritted glazes the color is not altered.

MOUNT APATITE. TOWNE QUARRY.

On the west slope of Mount Apatite and 100 yards below the highway is a dike (34) from which several hundred tons of good pottery feldspar has been obtained. The dike has a northeast strike and is almost vertical. It averages about 25 feet wide and has been opened to a depth of about 20 feet. The dike has an extremely irregular structure and contains a number of lenses of almost pure feldspar which is a microcline with intergrowths of albite. This feldspar has a deformation range of 1,270° to 1,285° and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard mixture of this feldspar vitrifies at 1,280° C. and at 1,330° C. shows a slight tendency to warp. The color is equal to that of the standard trial. Fired at 1,330° C. the total shrinkage is 13.8 per cent, the translucency is 0.640, and the color by transmitted light is a cream-white. Under the raw-lead and fritted glazes the color of the porcelain is unchanged.

AUBURN. GREENLAW QUARRY.

The Greenlaw Quarry (35) was opened several years ago on top of Mount Apatite, 3 miles west of Auburn.

The deposit consists of an irregular lens of graphic granite, of moderate coarseness and fair uniformity, similar to the other deposits on Mount Apatite. This property has been worked at various times for gem material and at present (1914) the feldspar production is of secondary importance, although the operator finds no difficulty in disposing of the quarried material, the output being used at the feldspar mill at Littlefield Station, 3½ miles southwest of Auburn and 2 miles south from this deposit.

This material was sampled and found to have a deformation range between 1,270° and 1,280° C. Heating above 1,280° caused it to quickly flow, which indicates that the alkali content is largely soda. The results of a chemical analysis of this material were as follows:

Composition of graphic granite from Greenlaw quarry.

	Per cent.
SiO_2	71.55
Al_2O_3	18.11
Fe_2O_3	0.16
CaO	0.46
MgO	Trace.
Na_2O	8.72
K_2O	0.64
	99.64
Combined H_2O	.75

The color of this material is a faultless white.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the feldspar vitrifies at 1,280° C. and at 1,330° C. warps slightly. The color is a matt white and when struck the porcelain has the characteristic ring which is peculiar to soda feldspar porcelains.

Fired at 1,330° C. the total shrinkage is 14.1 per cent, the translucency is 0.647, and the color is cream. The color is not altered by application of either raw-lead or fritted glaze.

AUBURN. MAINE QUARRIES.

There are a series of more or less connected pits (36, 37) on the crest of Mount Apatite, 3 miles west of Auburn.[a] None of the workings are deep, the maximum depth being about 25 feet. This is due to the fact that the dike consists of irregular folded bands, the valuable material being chiefly in pockets or lenses in very low-grade material The dike or dikes on the summit of Mount Apatite were first worked for the gem minerals which are occasionally found associated with pegmatite. In the search for gems many small pits were opened, and where merchantable feldspar was encountered this was later removed and if a good grade of pegmatite was indicated the quarrying was continued until low-grade material was encountered. Prospecting has not been systematic and doubtless much valuable pegmatite and feldspar still remain on this tract.

The pegmatite varies greatly, consisting of pure lenses of feldspar and massive quartz in some places and fine-grained graphic granite in others. All the associate minerals in pegmatite are encountered on this property. Both muscovite and biotite mica are common but the muscovite generally is in book form and is seldom scattered throughout the pegmatite. The biotite sometimes occurs as lath-shaped crystals but is generally found in limited areas and can be eliminated if care is exercised in sorting the quarried material. Garnets and black tourmaline are found in limited areas but are not abundant in the pegmatite rich in feldspar. Beryl is found in the feldspar lenses but generally has a pronounced blue color and can be easily detected and removed. Apatite and gem tourmaline occur in pockets of albite and are scattered throughout the dikes.

The feldspar constituent of these dikes is a buff to cream microcline with intergrowths of albite. Bastin[b] gives the results of an analysis by the United States Geological Survey as follows:

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[a] For a description of these deposits see Bastin, E. S., Economic geology of the feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, 1910, pp. 24-25.

[b] Bastin, E. S., Op. cit., p. 24.

Composition of feldspar from Maine quarry.

	Per cent.
H_2O	0.48
SiO_2	65.73
Al_2O_3	[a]19.28
CaO	.22
MgO	.00
K_2O	10.26
Na_2O	4.08
	100.05

This feldspar has a deformation range of 1,265° C. to 1,280° C., and fuses to a semitransparent mass of excellent color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

A standard mixture of this feldspar vitrifies at 1,280° C., and at 1,330° C. shows slight warping. Its color is equal to that of the standard trial. Fired at 1,330° C. the total shrinkage is 13.8 per cent and the translucency is 0.650, the color being cream white. The raw-lead and fritted glazes do not alter the color of the porcelain.

AUBURN. PEGMATITE DEPOSIT.

There is a feldspar deposit[b] (38) on the south slope of Mount Apatite, 3½ miles west of Auburn, which consists of an irregular lens of considerable extent and a number of stringers. The material is chiefly coarse pegmatite with a varying content of impurities, which are garnet, tourmaline, muscovite, biotite, and beryl. A great many other gem minerals have been found in this immediate neighborhood and this dike or lens has been worked irregularly in the hope of locating a pocket of valuable minerals. The pegmatite constituting the main part of the mass can be cleaned by hand sorting and a considerable amount of high grade material obtained for ceramic use. The exposed parts were sampled. This material was found to have a deformation temperature of 1,270° C. to 1,285° C. and an excellent color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the feldspar vitrifies at 1,280° C. and at 1,330° C. no warping is noted. The color is equal to that of the standard trial. Fired at 1,330° C. the total shrinkage is 14 per cent, the translucency is 0.670, and the color by transmitted light is cream white.

AUBURN. HAVEY QUARRY.

The Havey feldspar quarry (39), about 3½ miles west of Auburn, has been opened only a few years, and adjoins the Berry quarry, being on the same dike. The material appears the same, but the structure of the dike is even more lenticular than the Berry operations indicate. The soda feldspar present is almost entirely cleveландite and the quarrying is necessarily carried on with special care on account of the possible presence of gem material in all parts of the quarry. The remarkable running out of the pegmatite at a depth of about 20 feet, which was observed in both quarries, is apparently due to an abrupt folding of the dike, which above the fold seems to be almost vertical but below it is very irregular wherever exposed.

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[a] Includes trace of iron and any TiO_2 and P_2O_5 that may be present.

[b] Bastin, E. S., op. cit., pp. 25-26.

The feldspar deforms at 1,270° C. to 1,285° C., and fuses to a semitransparent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

This feldspar produces vitrification at 1,280° C., and at 1,330° C. no warping is apparent. The color is similar to that of the standard trial. Fired at 1,330° C. the total shrinkage is 14.2 per cent and the translucency is 0.665. The color is not affected by applying either the raw-lead or fritted glaze.

AUBURN. BERRY QUARRY.

The Berry feldspar quarry (40) is located on the southwest bank of the Little Androscoggin River, 1 mile southwest of Mount Apatite and 3½ miles west of Auburn.

The deposit[a] consists of an exposed lens in a dike trending north and south and containing a number of large lenses of excellent feldspar and numerous smaller lenses of gem-bearing material. This property has been worked for both feldspar and gem minerals and has been very productive. Owing to the sudden change from pegmatite to impure granitelike material, mining has only been carried to a depth of about 20 feet. In the vicinity of the gem-bearing deposits are lenses of the soda feldspar clevelandite, with which are associated lenses of massive albite. This material has a comparatively high deformation temperature, but has the short deformation characteristic of soda feldspar. The quantity of this material, however, is too uncertain to justify extensive investigations. The potash feldspar, however, which constitutes the major part of this deposit, is of a very uniform quality. It has a deformation temperature of 1,270° to 1,285° C. and an excellent color.

MASSACHUSETTS.

HAMPTON COUNTY.

RUSSELL. BLANDFORD QUARRY.

The Blandford quarry (121) is one-half mile north of Blandford and 4 miles from the railroad at Russell, Mass., in a dike exposed along a ridge running northwest and southeast. The dike is composed of

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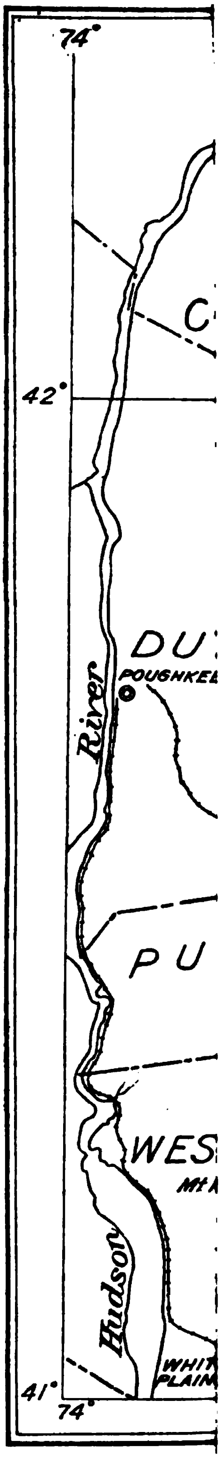
[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 26-27.



SKETCH MAP OF

several bands of pegmatite, varying widely in their feldspar content. Some of the bands are 12 to 15 feet wide in places and have a considerable content of massive feldspar; the deposit also contains much massive white sugar quartz. The property has been opened both on the hilltop and along the face. In one place an opening about 60 feet long and 20 feet wide has been made, and along the walls of the dike considerable muscovite of good quality has been removed. At the south end of this opening the feldspar is about 10 feet wide; whereas at the north end the sugar quartz has almost completely replaced the feldspar. Pure feldspar, however, is observed in smaller openings to the north of this main opening, and it would be assumed that the quartz rapidly pinches out beyond the limits of the main workings. The feldspar appears to be of excellent quality.

The deposit was somewhat covered by refuse from abandoned workings several years old, but samples were obtained by using care. Tests of the samples indicate that the range of deformation lies between 1,270° and 1,285° C. The feldspar is slightly more creamy than the Maine feldspar, but nevertheless is of excellent quality. In the standard porcelain body it has a shrinkage of 15 per cent and a translucency of 0.633.

CONNECTICUT.

HARTFORD COUNTY.

SOUTH GLASTONBURY. CURTIS QUARRY.

The Curtis quarry (44) is located in a deposit[a] 3 miles east of South Glastonbury. Two openings have been made, and in each of them the deposit strikes northeast and has vertical walls. The larger of these openings, which extends the full width of the dike, is about 30 feet wide and 300 feet long; the smaller one is about 150 feet long and 12 feet wide. The maximum depth of the workings is about 25 feet and the quality seems to be continuous, at least to this depth. The dike is composed of fine-grained pegmatite that contains cream-colored feldspar. No masses of pure feldspar larger than a few inches in diameter were noted. Considerable muscovite is scattered through the deposit, but it is practically all of small size and the quality seriously injured by ruling. Garnet occurs at a number of places in the deposit, but is not present over large areas and hence is not a serious detriment.

The extent of the deposit could not be definitely determined owing to the operations being confined to this property, but tests made on property adjoining on the east indicates that the dike continues with reasonable uniformity in that direction for a considerable distance.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, p. 42.

The pegmatite in this deposit was tested and found to have a deformation range of 1,280° to 1,295° C., and to be notably affected by the high quartz content. In the standard porcelain mixture the shrinkage was 13 per cent and the translucency 0.663. This translucency is remarkably high for the shrinkage properties displayed.

SOUTH GLASTONBURY. WIARDA QUARRY.

The Wiarda quarry (45) is located in a feldspar deposit[a] on a north and south ridge on the outskirts of South Glastonbury. Several irregular dikes are exposed, but little actual development work has been done to indicate the continuity of any particular dike or to ascertain the width of the bands rich in feldspar. A good quality of feldspar and graphic granite have been obtained from this property and 2,000 tons were reported as being quarried in 1911. The overburden is very light. The deposit does not differ materially from that of the Howe quarry, of which it is undoubtedly a continuation.

Muscovite and biotite are observed in some of the openings, but little merchantable mica of the white variety is noted. The feldspar is of a creamy color and has a deformation range of 1,275° C. to 1,290° C. It fuses to a semitransparent mass with a faint blue cast.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard porcelain mixture of this feldspar vitrifies at 1,290° C., and at 1,330° C. No warpage is noted. The color is slightly inferior to that of the standard trial. Fired at 1,330° C. the total shrinkage is 14.4 per cent, the translucency is 0.643, and the color by transmitted light is cream white. The color is not affected by either the raw-lead or the fritted glaze.

SOUTH GLASTONBURY. OLD WIARDA QUARRY.

The old Wiarda quarry[b] (46) is 1 mile south of South Glastonbury and one-eighth mile east of the highway. The quarry, which has been abandoned, worked a deposit consisting of several small dikes or stringers, evidently of the same dike that furnishes the pegmatite farther south. This dike is a mixture of fine-grained pegmatite and graphic granite. The feldspar is chiefly microcline of a light-buff color mixed with a small amount of albite. This feldspar when free from quartz has a deformation range of 1,270° C. to 1,285° C. and fuses to a semitransparent glass of good color.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 44-45.

[b] Bastin, E. S., Loc. cit.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280° C. and warps slightly at 1,330° C. The color is seen to be a light gray when compared to the standard trial. Fired at 1,330° C. the total shrinkage is 14.2 per cent, the translucency is 0.640, and the color by transmitted light is cream. The gray color is intensified under the raw-lead and also under the fritted glaze.

SOUTH GLASTONBURY. OLD EUREKA QUARRIES.

Located just north of the Howe quarry are the old Eureka quarries (47), two quarries which appear to contain much commercial feldspar, but which have not been operated for several years. The dike structure is a medium coarse pegmatite containing small lenses of pure feldspar. Iron-bearing minerals show in the exposed faces only in small amount. Samples of the feldspar show a deformation range of 1,270° C. to 1,285° C. and fuse to a semitransparent glass of good color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture this feldspar vitrifies at 1,280° C. and warps slightly at 1,330° C. The color is only slightly inferior to that of the standard trial. Fired at 1,330° C. the total shrinkage is 14.2 per cent, the translucency is 0.645, and the color is cream by transmitted light. Under the raw-lead and fritted glazes the color is unaltered.

SOUTH GLASTONBURY. LOUIS W. HOWE QUARRY.

The Louis W. Howe quarry (48), which is the largest operation in Connecticut, is 2 miles south of South Glastonbury and 3 miles east of Rocky Hill.

The deposit[a] consists of an enormous dike, which at the time of visiting had been opened for a distance of 650 feet and an average width of about 100 feet to a depth of 70 feet, showing a good quality of pegmatite the entire depth. The structure is a coarse pegmatite, which in some places grades into graphic granite. Mica is not present in large quantity, but small crystals of muscovite occur throughout the greater part of the deposit, and biotite shows over limited areas at a few places in the part exposed. Garnet is in such small quantity and so well crystallized that its removal by hand sorting is practicable. A few places contain tourmaline of the black variety, which also is easily separated in the hand sorting.

The dike is considerably wider than the opening indicates, but the eastern part is much more impure and is not considered of commercial quality, hence it has not been disturbed. The workings had been carried vertically to a depth of about 70 feet and formed a pit, from which it was necessary to hoist the material by a bucket system, the water which drains into the quarry being removed by pumping. The formation has been worked in benches 10 feet high and 3½ feet wide. Cars of 1½ tons capacity and running on steel tracks conveyed the material from the face of the workings to the point where it was lifted to the surface by buckets. The material, after being hoisted to the surface, was hand sorted according to quality, and the accepted material conveyed by wagon to the mill at South Glastonbury.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 45-46.

The intimate mixture of feldspar and quartz in this dike precludes the production of a feldspar free from quartz, but by selection the quartz content can be maintained at as low a percentage as is now practicable in the Maine quarries.

The feldspar of this deposit has the following composition:

Composition of feldspar from Louis W. Howe quarry.

	Per cent.
H_2O	0.00
SiO_2	65.64
Al_2O_3	19.10
Fe_2O_3	.14
CaO	Trace.
MgO	Trace.
Na_2O	2.32
K_2O	12.58
	99.78

This feldspar has a deformation range of 1,275° C. to 1,290° C. It fuses to a semitranslucent mass with a faint blue tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture this feldspar vitrifies at 1,290° C. and at 1,330° C. shows no signs of warpage. The color is slightly inferior to that of the standard trial. Fired at 1,330° C., the standard mixture shows a total shrinkage of 14 per cent and has a cream-white color by transmitted light and a translucency of 0.647. This feldspar should be equal to the Maine feldspar for all ceramic purposes if equal care were exercised in the selection.

MIDDLESEX COUNTY.

ROCKY HILL. ANDREWS QUARRY.

The Andrews quarry[a] (49) is located in Portland Township, 4½ miles southeast of Rocky Hill. This dike forms a ridge with a general north and south trend and has been opened to a depth of about 50 feet and a length of about 150 feet. The deposit consists of a graphic granite and fine-grained pegmatite mixture which has a very uniform quartz content and a cream-colored feldspar content. Muscovite is reasonably abundant, but rarely in large crystals, and would have little commercial importance aside from mica for grinding. Small crystals of black tourmaline and garnet are also scattered through the deposit, and would require removal by hand sorting where very abundant.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 50-51.

An analysis of the material in this deposit is given by Bastin,[a] as follows:

Composition of graphic granite from Andrews quarry.

	Per cent.
SiO_2	71.00
Al_2O_3	16.31
MgO	.00
CaO	.22
Na_2O	3.44
K_2O	8.66
H_2O	.12
	99.75

The material from this deposit, free from other than quartz impurity, was sampled and found to have a deformation range of 1,270° to 1,285° C. It fuses to a semitransparent glass with a faint blue tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture this feldspar vitrifies at 1,280° C., and at 1,330° C. no warping is evident. Its color is similar to that of the standard trial, but shows a faint gray tint. Fired at 1,330° C., the total shrinkage is 13.4 per cent, the translucency is 0.673, and the color a cream white. The raw-lead glaze and the fritted glaze darken the porcelain slightly.

PORTLAND. EUREKA QUARRY.

The Eureka quarry[b] (50) is located 2½ miles northeast of Portland on the west slope of Collins Hill. At the time of visiting the opening was about 185 feet long and 65 feet wide. The deposit consists of a capping of impure schist 5 to 15 feet thick underlaid by pegmatite consisting of cream to white feldspar and gray and white quartz, with small lenses of albite at a number of places. Narrow bands or stringers of material similar to that of the main dike occur on both sides of it. Where exposed the dike seems to be about 12 to 20 feet wide and the west dike or stringer seems to be exceptionally high in soda feldspar. This property had been opened to a depth of 30 feet in the main cut and a smaller dike to the west had been opened on a level about 30 feet below the main cut.

The pegmatite contains only a moderate quantity of muscovite which is seldom of a commercial quality. Biotite and garnet are present only in a few parts of the dike and could be eliminated with little difficulty. Black tourmaline is scattered throughout the dike but is coarsely crystalline and does not present any great difficulty in sorting it from the marketable material. This deposit should not be worked for pure feldspar, but by careful selection the quartz content can be maintained sufficiently low to make a high-grade pottery feldspar. The potash feldspar present is a microcline and is intimately intergrown with albite. A sample of this material was cleaned of its free quartz content and an analysis made, showing the following composition:

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[a] Bastin, E. S., Op. cit., p. 14.

[b] For a description of this deposit see Bastin, E. S., Op. cit., pp. 51-52.

Composition of feldspar from Eureka quarry.

	Per cent.
Loss on ignition	0.25
SiO_2	65.24
Al_2O_3	19.74
Fe_2O_3	.12
CaO	.00
MgO	.00
Na_2O	3.04
K_2O	11.84
	100.23

This feldspar has a deformation range of 1,270° C. to 1,285° C. It fuses to a semitransparent glass with a faint blue tint. The soda feldspar associated in lenses with the above microcline shows a deformation range of 1,255° C. to 1,265° C. Its color when fused is an excellent enamel white.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the potash feldspar vitrifies at 1,280° C. and does not warp at 1,330° C. The color is slightly below that of the standard trial. Fired at 1,330° C. the total shrinkage is 14 per cent, the translucency is 0.653, and the color cream white. The color of the porcelain is unaltered under the fritted glaze but under the raw-lead glaze is slightly darker.

The soda feldspar in the standard porcelain mixture vitrifies at 1,260° C. and at 1,330° C. shows slight warpage. The color is a matt white. Fired at 1,330° C. the total shrinkage is 13.2 per cent and the translucency is 0.643. The color is not altered under the raw-lead and the fritted glazes.

MIDDLETOWN. RIVERSIDE QUARRIES.

One-fourth mile west of the Consolidated quarry and near the Connecticut River are two dikes (51, 52) of coarse pegmatite containing much massive sugar quartz from which the hill has received the name of White Rock Ridges. The extent of the dikes has never been determined, but there are numerous exposures over a considerable area. The general strike of the dike is nearly due north and south. The dike farthest west is a mixture of graphic granite and coarse buff pegmatite. A small amount of garnet and biotite are the chief impurities. This dike has been worked on a limited scale at a number of points and shows fair uniformity wherever opened.

The east dike is a widely varying mixture of potash feldspar pegmatite and soda feldspar pegmatite. It is much smaller in extent than the west dike and shows a structure similar to the gem bearing dikes of Maine. Much clevelandite is scattered through this dike, and black, pink, and green tourmaline are noted, although the tourmalines are all opaque and not of the gem quality. The albite parts of the deposits are of doubtful value, but the potash feldspar pegmatite, which is similar in both dikes, shows a good color and has a deformation range of 1,275° to 1,290° C.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

This feldspar, in the standard porcelain mixture, gives a vitrious product at 1,290° C. and shows no warpage at 1,330° C. The color is equal to that of the standard trial. At 1,330° C. the translucency is 0.680 and the total shrinkage is 13.9 per cent. The color is unaltered under either the raw-lead or the fritted glaze.

MIDDLETOWN. CONSOLIDATED QUARRY.

The Consolidated Feldspar quarry[a] (53) is located 3 miles east of Middletown, Conn., at an elevation of nearly 500 feet above the Connecticut River. The dike has been opened along a northeast face, showing a width of about 50 feet. The composition of the dike is decidedly variable. In many places it is remarkably free from impurity and shows considerable masses of pure buff feldspar of the potash variety; in others it is very fine-grained pegmatite with much mica and small garnets. The gradation is so pronounced, however, that no difficulty in sorting would be experienced.

The feldspar content of this dike was sampled and shows by chemical analysis the following composition:

Composition of feldspar from Consolidated Feldspar quarry.

	Per cent.
SiO_2	66.03
Al_2O_3	18.99
Fe_2O_3	0.08
CaO	None.
MgO	None.
Na_2O	3.12
K_2O	10.96
	99.18

It has a deformation range from 1,275° to 1,290° C. and fuses to a translucent mass free from tint.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 49-50.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280° C. and at 1,330° C. shows no evidence of warping. The color is equal to that of the standard trial and does not alter under either the raw lead or the fritted glaze. Fired at 1,330° C., the total shrinkage is 14.2 per cent and the translucency is 0.673 and the color cream white.

MIDDLETOWN. BIDWELL QUARRY.

The Bidwell quarry (54) is located 2½ miles south of Middletown, on Haddam Pike. The quarry was worked about 40 years ago, and recently has been reopened and worked for its pegmatite. The deposit consists of a dike which strikes due north and has been mined to a depth of 20 feet for a distance of about 200 feet. The material removed is reported to have been buff potash feldspar, but that now exposed in the walls and floor consists of about equal proportions of microcline and albite. This quarry should produce a considerable amount of mixed feldspar high in soda content and valuable for softening the feldspars high in potash. An average sample of the feldspar shows a deformation range of 1,265° to 1,275° C. and fuses to a semiopaque enamel of good white color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,270° C. and shows pronounced warping at 1,330° C. The color is a faint gray. Fired at 1,330° C. the shrinkage is 13.8 per cent and the translucency is 0.630 and the color is cream. The application of raw lead and fritted glazes intensifies slightly the gray tint of the unglazed porcelain.

MIDDLE HADDAM. HALLBERG DEPOSIT.

The Hallberg deposit (55), 2 miles southeast of Middle Haddam village, does not differ materially from the one at the Middle Haddam quarry, except that gem minerals are absent. The dike is opened by a pit at its northeast terminus on an abrupt bluff of a hill. The width of the dike where exposed in this pit is about 20 feet, and a face about 20 feet high has been uncovered.

The pegmatite in this deposit was sampled and found to have a deformation temperature of from 1,270° to 1,285° C.

It fuses to a semitransparent glass with a faint blue tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the above feldspar vitrifies at 1,280° C. and at 1,330° C. a slight warpage is noted. Fired at 1,330° C., the total shrinkage is 14.5 per cent, the translucency is 0.657, and the color is cream. The porcelain shows a faint gray tint which is intensified by the application of both the raw lead and the fritted glaze.

MIDDLE HADDAM. MIDDLE HADDAM QUARRY.

The Middle Haddam quarry (56), 1½ miles southeast of Middle Haddam village, consists of a number of small openings scattered over a territory comprising several hundred acres. The largest single operation consists of an opening in the west slope of a hill overlooking the Connecticut River and the dike where exposed seems to be about 40 feet wide and to have a general northeasterly strike. This deposit is about one-half of a mile from the river and the material is hauled to the face of an abrupt cliff and dumped into lighters moored below it.

The product of the quarry is a granite pegmatite, practically no lenses of pure feldspar being observed. Crystals of muscovite of moderate size occur at frequent intervals, but few specimens of commercial value are noted. Black tourmaline and biotite are scattered through the deposit and require careful hand sorting to eliminate them. The occurrence of lepidolite and colored tourmaline are reported from this deposit, but none was observed at the time of its inspection. The cleaner parts of the pegmatite were sampled and found to have a deformation temperature of 1,270° to 1,285° C. When fused the feldspar is semitransparent and has a faint blue tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280° C., and at 1,330° C. warps slightly and has a faint gray tint. When fired at 1,330° C. the total shrinkage is 14 per cent and the translucency is 0.630 and the color is cream. Under the raw-lead and fritted glazes the gray tint is somewhat intensified.

HADDAM. HADDAM NECK QUARRY.

Haddam Neck quarry (57) is located on the east bank of the Connecticut River, opposite Haddam village. This deposit consists of a dike about 100 feet wide and has been worked for a distance of about 350 feet and to a depth of about 30 feet. The deposit contains a variable pegmatite with many inclosed masses of albite and small lenses of microcline; graphic granite was exposed in many parts of the quarry when visited. The pegmatite is mixed with micas, black tourmaline, garnet, and other minerals and many gems are reported as being found in this quarry. The feldspar is a buff microcline intergrown with albite of a white and pale-green color. Free from quartz, this feldspar shows a deformation range from 1,266° to 1,285° C., and when fused is semitransparent and has a good color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280° C., and at 1,330° C. no warping is noted. The color is almost equal to that of the standard trial. Fired at 1,330° C. the total shrinkage is 14 per cent and the translucency is 0.637 and the color is cream white. The color is not altered under the raw-lead and fritted glazes.

NEW HAVEN COUNTY.

OXFORD. BRIDGEPORT QUARRY.

The Bridgeport quarry is located about 1½ miles south of Oxford, Conn. This quarry is an open pit about 150 by 100 feet in size and the deposit[a] seems to be an isolated lens of pegmatite which apparently does not continue in either direction. The quarry has been abandoned some time and at the time of visiting was filled with water so that no estimate of what its content was, or what material the walls are, could be formed. The parts exposed above the water consist largely of a coarse pegmatite with isolated lenses of feldspar of widely varying color and structure. The quartz in this quarry is reported as having been rose quartz and massive white sugar quartz. The quantity of feldspar exposed is not sufficient to justify a statement regarding the probable quality of the feldspathic material of the deposit.

NEW YORK.

All the feldspar deposits investigated in New York are shown in Plate VI except those in Westchester County, which are shown in Plate V.

ESSEX COUNTY.

CROWN POINT. CROWN POINT QUARRY.

The Crown Point quarry (58) is 2 miles southwest of Crown Point and 1 mile west of Lake Champlain. The deposit[b] is an expanded pegmatite dike, of widely varying composition, with a northeast strike. The dip is uncertain, but is almost vertical where exposed by quarrying for a width of about 40 feet.

The pegmatite is a coarse mixture of pearl-gray microcline and green plagioclase with variable contents of quartz and leaves of biotite along the contact faces between the masses of microcline and plagioclase. In this quarry the central part of the dike contains more microcline than plagioclase, and along the walls the plagioclase appears to predominate. Along the west wall a hematite-red stain occurs on the faces of the microcline crystals, but does not penetrate the feldspar masses. The overburden varies from nothing to 4 feet and is a soil made up largely of weathered dike material.

The nature of the deposit would demand great care in selecting the feldspar if it were to be marketed for ceramic uses. Many parts are so mixed with biotite that cleaning would be impracticable, but at least one-third of this dike would justify cobbing for its microcline. The mining at present is for material to be used in the manufacture of roofing and for poultry grit, and for these purposes the run of the quarry can be used without cleaning of any impurity except the small

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 53-54.

[b] See Bastin, E. S., Op. cit., pp. 54-55.

SKETCH MAP OF PART OF NEW YORK (S

flake mica. The greater part of the mica can be eliminated by means of a screen, as it does not pulverize with the feldspar.

Although the output of pottery feldspar from such a deposit would necessarily vary greatly in different parts of the dike, the small quartz content would make such good feldspar as was obtained of especial value for the improvement of pegmatite high in quartz and would eliminate the necessity of robbing other dikes of their select feldspar for this purpose.

The two types of feldspar present in the dike were sampled separately and tested.

The microcline is found to have the following chemical composition:

Composition of microcline from Crown Point quarry.

	Per cent.
Ignition loss	0.40
SiO_2	63.61
Al_2O_3	19.09
Fe_2O_3	.43
TiO_2	.02
CaO	.54
MgO	.17
BaO	.15
K_2O	14.07
Na_2O	1.73
	100.21

The microcline has a deformation range of 1,270° to 1,285° C. and fuses to a semitransparent glass of faultless color. The plagioclase has a deformation range of 1,280° to 1,290° C. and fuses to a light brown slag. From 400° C. until deformation begins this plagioclase is a hematite-red color, and at 1,275° C. shows no signs of vitrification.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The microcline of this deposit, when prepared in the standard porcelain mixture, vitrifies at 1,280° C., and at 1,330° C. shows no warpage. Fired at 1,330° C. the total shrinkage is 14.6 per cent, the translucency is 0.84, and the color is cream white. The color is equal to that of the standard trial and is not altered under either the raw-lead or the fritted glaze.

TICONDEROGA. BARRETT QUARRY.

The Barrett quarry (59) is 1¾ miles northwest of Ticonderoga, and almost due south of Crown Point quarry. The deposit,[a] which closely resembles that at the Crown quarry, as regards structure and constituents, is a dike 100 to 150 feet wide, and is exposed for about 1,200 feet along the east slope of a ridge which strikes northeast and dips 35° SE. The dike is opened to a maximum depth of 60 feet. The pegmatite exposed is a coarse mixture of pearl-gray microcline and pale-green plagioclase, the analysis of which shows it to be andesine. Biotite is very abundant and is distributed throughout the dike. It generally occurs along the contacts between the microcline and the oligoclase, and as neither feldspar averages masses more than 5 or 6 inches in diameter, the removal of the biotite presents a serious problem. Where the oligoclase is not so abundant the microcline occurs with the quartz as graphic granite. The biotite in this dike is remarkably tough and does not reduce to a powder when passed through the crushing machinery employed to reduce the feldspar to the proper size for roof covering, for which purpose the output of the quarry is used. The microcline has a very highly developed cleavage and attempts at cobbing result in its breaking into fragments of one-fourth to one-sixteenth inch in diameter. The logical method of cleaning this microcline is to granulate it and then separate it from the biotite by screening or blowing. Up to March, 1915, all attempts to eliminate the biotite completely have failed, and it is doubtful if this deposit can be made to produce a large amount of high-grade feldspar unless some special system of separating the biotite can be developed.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 55-56.

The feldspar constituents of the dike were sampled carefully and found by analysis to have the following compositions:

Composition of feldspar constituents of Barrett deposit.

		Pearl-gray microcline.	Pale green andesine.
Ignition loss	per cent..	0. 18	0. 58
SiO_2	do....	64. 55	59. 35
Al_2O_3	do....	18. 90	25. 30
Fe_2O_3	do....	. 36	. 57
TiO_2	do....	. 03	. 03
CaO	do....	. 51	6. 43
MgO	do....	. 19	. 00
BaO	do....	. 19	. 00
K_2O	do....	12. 32	1. 35
Na_2O	do....	2. 88	6. 26
		100. 11	99. 87

The microcline has a deformation range of 1,260° to 1,275° C. and fuses to a semitransparent glass of faultless color.

The andesine has a deformation range of 1,330° to 1,335° C. and fuses to a light-brown slag. From 400° C. until deformation begins the andesine is a hematite red and shows no signs of vitrification at 1,275° C., although it contains more than 60 per cent albite.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture the microcline vitrifies at 1,270° C. and at 1,330° C. warps slightly. Fired at 1,330° C. the total shrinkage is 13.7 per cent and the translucency is 0.86 and the color is cream white. The color of the porcelain is equal to that of the standard trial and is not altered under either the raw-lead or the fritted glaze.

TICONDEROGA. TICONDEROGA QUARRY.

The Ticonderoga quarry (60) is 1 mile southeast of Ticonderoga, an the south side of the railroad between Ticonderoga and Mont Calm Landing, in a small glen facing northeast and having very abrupt walls. A face about 60 feet high and 30 feet wide has been worked for a depth of about 20 feet. The dike consists of a medium coarse pegmatite with massive intrusions of calcite and these calcite masses, as well as the lines of contact between the feldspar and the calcite, carry large amounts of finely crystallized hornblende. The dike is so completely charged with these minerals that the production of a pure feldspar would be very expensive if not quite impossible.

SARATOGA COUNTY.

CORINTH. CORINTH QUARRY.

The Corinth feldspar quarry [a] (61) is 2½ miles southwest of Corinth station. The quarry consists of a small pit opened on the east face of a hill, and another and larger opening 100 yards distant and 125 feet higher, and following the strike of the dike for about 50 feet. This latter opening is so shallow, however, that it is doubtful if it shows the true nature of the dike, as the lines of contact and capping often show more impurity than the body of the dike, and the associated minerals exposed, garnet and biotite, are similar to those of the inclosing rocks, which are schists. The lower opening is a very pure pegmatite and graphic granite consisting of pearl-gray microcline and smoky quartz. No other minerals are present.

The chief difficulty in the development of this property is the poor road to the railroad, but if the road was improved the expense of hauling, as almost the entire distance is down hill, could be reduced to the minimum. The two pits were sampled separately and tested.

The feldspar of the upper pit shows a deformation range of 1,255° to 1,265° C., and when fused is almost transparent and free from tint.

The feldspar of the lower pit shows a deformation range of 1,260° to 1,270° C., and when fused is semitransparent and free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture the feldspar of the upper pit vitrifies at 1,260° C. and at 1,330° C. warping is evident. Fired at 1,330° C. the total shrinkage is 14.8 per cent, the translucency is 0.74, and the color is cream white. The color of the porcelain is equal to that of the standard trial and is not altered under either the raw-lead or fritted glaze.

In the standard porcelain mixture the feldspar of the lower pit vitrifies at 1,270° C., and at 1,330° C. no warpage is apparent. Fired at 1,330° C. the total shrinkage is 15 per cent, the translucency is 0.83, and the color is cream white. The color is equal to that of the standard trial and is not altered under either the raw-lead or the fritted glaze.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 57-58.

BATCHELLERVILLE. BATCHELLERVILLE QUARRIES.

The Batchellerville quarries (62) are 2 miles north of Batchellerville and one-fourth mile east of the Day-Batchellerville road.

MAIN QUARRY.

The main quarry is on a west slope and is in full view of the road.[a] At the time of visiting it consisted of a cut about 60 feet long and 35 feet wide into a pegmatite dike which strikes northeast and stands almost vertical. The cut slopes into the hill and was filled with water to the entrance, but a face 20 feet high was exposed above the water. The pegmatite, which is coarsely crystalline, consists of cream and pearl-gray microcline and white albite mixed with gray quartz. Rose-colored sugar quartz is present in large masses. A small lens of pure albite was noted in the floor near the entrance. Muscovite is present, but is segregated and could be easily eliminated in handling the quarried material. Beryl is found, but is of a dark blue color and would be quickly recognized and rejected in handling the material. The limited quantity of biotite would present no serious difficulty in mining the feldspar.

The wall rock is a biotite gneiss, and there is a horse of similar rock in the center of the dike, but it is perfectly solid and would not present any serious hindrance to quarrying.

Samples of the microcline were obtained free from albite and quartz, and this shows a deformation range of 1,270° to 1,285° C. It fuses to a glass which is semitransparent and free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280° C., and at 1,330° C. shows no sign of warping. Fired at 1,330° C. the total shrinkage is 15 per cent, the translucency is 0.78, and the color is cream white. The color is equal to that of the standard trial and is not affected by the raw-lead and fritted glazes.

SECOND QUARRY.

A second quarry is located about 100 yards east of the main quarry and on the strike of the same dike, but on ground 60 feet higher. This opening was only about 20 feet wide and 30 feet long, and had a maximum depth of 10 feet. The composition of the dike at this point is slightly different, although in most respects it is similar to the lower quarry exposure. The microcline is entirely of the pearl-gray variety. Muscovite is present in only limited amount and no biotite is noted. Dark-red, cloudy garnets are noted in limited numbers, but these are generally large and hence easily detected and removed. Some graphic granite occurs in the walls of this opening, but its quartz content is very low.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 58-59.

A careful average was made of the feldspar content of this part of the dike, and this shows by analysis the following composition:

Composition of selected feldspar from smaller quarry.

	Per cent.
Ignition loss	0.26
SiO_2	65.14
Al_2O_3	19.38
Fe_2O_3	.29
TiO_2	.01
CaO	.44
MgO	.14
BaO	.00
K_2O	11.28
Na_2O	3.61
	100.55

This feldspar has a deformation range of 1,250° to 1,260° C. and fuses to an almost transparent glass of excellent color. The small content of CaO and MgO exert a remarkable influence in lowering the deformation temperature and shortening the deformation range. The presence of 0.29 per cent of Fe_2O_3 would be expected to produce a tint, but none is apparent.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,260° C., and at 1,330° C. the warpage is very pronounced. Fired at 1,330° C. the total shrinkage is 13.6 per cent, the translucency is 0.86, and the color is cream white. The color of the porcelain is equal to that of the standard trial, and the color is not altered under either the raw-lead or the fritted glaze.

THIRD QUARRY.

A third quarry (63) which has been worked only in a very primitive way is located one-fourth mile east of the upper quarry in a glen. Its location would indicate that this deposit is a continuation of the one worked in the two openings nearer the highway, especially as pegmatite is encountered by removing the surface soil in many places between the quarries. The appearance of the dike is, however, very different. Masses of deep salmon and pink feldspar of the microcline variety are exposed in a creek bed, and associated with this is a pegmatite consisting of pale pink feldspar and clear white quartz. The dark salmon and pink feldspar free from quartz have been removed from an opening 30 feet long and 20 feet wide and having an estimated depth of 12 feet. This pink and salmon feldspar were sampled and tested separately. The salmon feldspar, which predominates, was analyzed and found to have the following composition:

Composition of salmon feldspar from third quarry.

	Per cent.
Ignition loss	0.17
SiO_2	64.26
Al_2O_3	18.78
Fe_2O_3	.43
TiO_2	.00
CaO	.33
MgO	.14
BaO	.00
K_2O	14.15
Na_2O	2.01
	100.27

This feldspar shows a deformation range of 1,275° to 1,290° C. and fuses to a semitransparent mass with a fair color, but not equal to that of the lighter-colored feldspars. The pink feldspar has the same range and temperature of deformation as the salmon feldspar.

A sample of the pale pink feldspar was obtained from an exposure midway between the second and third quarries. This feldspar was found to have a deformation range of 1,265° to 1,275° C. and when fused it becomes almost transparent and free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

Salmon feldspar.—In the standard porcelain mixture the salmon feldspar vitrifies at 1,280° C., and at 1,330° C. shows no evidence of warping. When fired at 1,330° C. the total shrinkage is 13.6 per cent, the translucency is 0.82, and the color is cream white. The color of the porcelain is equal to that of the standard trial, and is not altered under either the raw-lead or the fritted glaze.

Pale pink feldspar.—In the standard porcelain mixture the pale pink feldspar vitrifies at 1,270° C., and at 1,330° C. showed slight warping. Fired at 1,330 C., the color is equal to that of the standard trial. the total shrinkage is 15.2 per cent, the translucency is 0.86, and the color by transmitted light is cream white. The color of the porcelain is not affected by application of either raw-lead or fritted glaze.

HAMILTON COUNTY.

NORTHVILLE. SNELL PROSPECTS.

On the Herbert Snell property (63) in Benson Township, Hamilton County, 4 miles north of Northville, Fulton County, numerous exposures of pegmatite were noted, the most promising being on a hill west of the highway, where a dike about 15 feet wide is exposed at two places. The deposit has a general northeast strike, and stands nearly vertical. Very little biotite or tourmaline were exposed and the pegmatite seems remarkably pure except for occasional lenses of massive quartz. The feldspar is principally a pale salmon microcline, but a short distance off the strike a small exposure of pearl-gray microline was noted.

The salmon feldspar was sampled and tested. It has a deformation range of 1,255° to 1,265° C., and when fused it is practically transparent and free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the feldspar vitrifies at 1,260° C. and at 1,330° C. shows warping distinctly. Its color is equal to that of the standard trial. Fired at 1,330° C. the total shrinkage is only 13 per cent; the color is cream white, and the translucency is 0.82. The color is not altered under the raw-lead and fritted glazes.

FULTON COUNTY.

NORTHVILLE. RHODES QUARRY.

The Rhodes quarry (64) is located about 3 miles northeast of Northville, Fulton County, near the Saratoga County line. This quarry was opened about 20 years ago and only a small quantity of feldspar has been removed. The opening, which is 20 by 30 feet, is filled with water and no data on the deposit could be obtained except from a quantity of clean feldspar, estimated at 30 tons, which is heaped about the opening. About 6 tons of massive quartz is also heaped near the quarry. There is a notable absence of pegmatite in this deposit and the only mineral noted aside from feldspar and massive quartz is clear mica, for which the quarry was originally opened. The feldspar is a buff microline intergrown with thin layers of quartz. These quartz layers constitute approximately 25 per cent of the mass. A sample representing the average of the heaps of feldspar showed a deformation range of 1,330° to 1,350° C. and fused to a semitransparent glass with remarkable freedom from color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture this feldspar produces a vitrious mass at 1,350° C. The color is equal to that of the standard trial. Fired at 1,330° C. the feldspar has a cream-white color and a translucency of 0.77, and a total shrinkage of 14.2 per cent. The color is not altered by the raw-lead and fritted glazes.

NORTHVILLE. GIFFORD PROSPECT.

The Gifford prospect (65) is 1½ miles west of Northville, in a pegmatite dike, 6 to 10 feet wide, which can be traced for one-half mile along an east slope. The degree of purity varies in the exposed faces, but as no development work had been done only surface indications could be noted. In many places lenses of pure feldspar 1 to 2 feet square are exposed, the degree of purity seeming to increase toward the south end of the dike. The feldspar is principally buff microcline, but pale salmon microcline is noted at a few points.

The buff microcline was sampled and tested. It has a deformation range of 1,265° to 1,275° C. and when fused is semitransparent and free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the feldspar vitrifies at 1,270° and at 1,330° C. warping is apparent. The color is equal to that of the standard trial. Fired at 1,330° C. the porcelain has a cream-white color by transmitted light, a translucency of 0.76, and a total shrinkage of 15 per cent. The color is not altered under the raw-lead and fritted glazes.

CRANBERRY. TYROL MOUNTAIN QUARRY.

The Tyrol Mountain quarry (66) is 2½ miles west of Cranberry station, in the crest of the Tyrol Mountain.

The dike[a] is exposed on a south slope and consists of a number of distinct bands. Some of these are very impure whereas others are almost free from minerals other than feldspar and quartz. At the time of visiting a mass of very impure pegmatite, which had been opened by the last operator of this property and not removed, the quarry face being covered with débris. Lenses of clean pegmatite were exposed on both sides of this impure mass and much high-grade pottery material may still be expected from this property. A lens of plagioclase, which is shown by analysis to be andesine, and much clean microcline pegmatite was exposed in the floor of the quarry.

The location of this deposit, about 1,000 feet above the railroad, indicated a very steep road and, although down hill, the conveying of the material to the railroad presents difficulties which could be overcome only by building a road of more gradual slope.

The results of an analysis of the andesine is as follows:

Composition of andesine from Tyrol Mountain quarry.

	Per cent.
Ignition loss	0.54
SiO_2	61.91
Al_2O_3	23.69
Fe_2O_3	.40
TiO_2	
CaO	4.37
MgO	.13
K_2O	1.17
Na_2O	8.40
	100.61

It shows a deformation range of 1290° to 1300° C. and fuses to a clear white enamel.

The pegmatite, which constitutes the vast majority of the deposit, is buff microcline and quartz. It deforms at 1270° to 1280° C. and fuses to almost a transparent glass without tint.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 56-57.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

Andesine.—In the standard mixture this andesine vitrifies at 1,300° C. and has a cream white color by transmitted light, a translucency of 0.76, and a total shrinkage of 14 per cent.

Microcline.—In this mixture the above microcline vitrifies at 1,280° C. and at 1,330° C. shows no warpage. Fired at 1,330° the microcline has a total shrinkage of 13.6 per cent, a cream white color by transmitted light and a translucency of 0.78. The color is equal to that of the standard trial and is not altered by the raw-lead and fritted glazes.

WESTCHESTER COUNTY.

BEDFORD. BEDFORD QUARRY.

The Bedford quarry (67) is located on the north slope of a hill, 1 mile east of Bedford village. The deposit is a dike or a stringer from the main dike which forms the central part of the hill and is worked at the Kinkel quarry. At the Bedford quarry it consists of two principal forms of feldspar, a buff microcline pegmatite and a white albite pegmatite. Associated with the microcline is a dark buff feldspar of the potash variety and almost free from quartz. The chief associate minerals are the micas, the biotite being in small crystals and associated chiefly with the albite pegmatite whereas the muscovite is distributed through the microcline pegmatite, but not in injurious quantity. The muscovite is extremely tough and withstands abrasion, and the major part of it could be eliminated by screening the material after a short preliminary grinding.

The entire dike is quarried and sorted. The parts high in albite and the standard feldspar are marketed for less critical uses and the better parts are sold for pottery manufacture. A sample of the pottery feldspar from this quarry has the following composition:

Composition of pottery feldspar from Bedford quarry.

	Per cent.
Ignition loss	0.28
SiO_2	69.45
Al_2O_3	16.76
Fe_2O_3	.20
TiO_2	
CaO	.45
MgO	.05
BaO	.10
Na_2O	2.60
K_2O	9.80
	99.69

This feldspar has a deformation range of 1,270° to 1,290° C. and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar produces a vitrious mass at 1,290° and shows no evidence of warping at 1,330° C. Fired at 1,330° C. it has a total shrinkage of 15.0 per cent, a cream color by transmitted light, and a translucency of 0.87. The color of the porcelain is slightly cream, but is equal to those of most commercial wares, and is not affected by application of either the raw-lead or the fritted glaze.

BEDFORD. KINKEL QUARRY.

The Kinkel quarry (68) is 1 mile east of Bedford village. The dike [a] into which this quarry has been opened constitutes the central part of a ridge which ends abruptly at this point. This dike has a total width of about 200 feet, but intrusions of material similar to the walls divide it into three sections which have been worked as separate quarries. The structure of this entire dike is extremely coarse. Enormous masses of clear quartz are associated with the feldspar, which is of four general types, namely, salmon microcline, buff graphic granite of the microcline variety, white albite pegmatite of varying coarseness, and a friable white albite evidently well advanced in weathering process.

MICROCLINE PEGMATITE.

The salmon microcline occurs in isolated lenses generally surrounded by massive quartz. It is remarkably free from associate minerals and could be obtained in a high state of purity by hand sorting. An average sample of this microcline has the following chemical composition.

Composition of microcline from Kinkel quarry.

	Per cent.
Ignition loss	0.22
SiO_2	64.82
Al_2O_3	18.87
Fe_2O_3	.29
TiO_2	.01
CaO	.23
MgO	.16
BaO	Trace.
K_2O	13.11
Na_2O	2.70
	100.41

It has a deformation range of 1,270° to 1,290° C. and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,290° and no warping is apparent at 1,330° C. Fired at 1,330° it has a cream-white color by transmitted light, a translucency of 0.78, and a total shrinkage of 14 per cent. The color is equal to that of the standard trial and is not affected by the raw-lead and fritted glazes.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, 1910, pp. 60-63.

GRAPHIC GRANITE.

The buff graphic granite, the quantity of which is small compared to that of the salmon microcline, is similar in all respects to that found on the adjoining property of the Bedford Feldspar Co.

ALBITE PEGMATITE.

The albite pegmatite is very important as it constitutes at least 50 per cent of the entire feldspar content of the dike.

The fact that biotite is distributed throughout many parts of this albite pegmatite will necessitate careful sorting if the more impure parts are to be rendered suitable for pottery uses. Much of the pegmatite, however, contains no biotite or other impurity except quartz and could be easily and cheaply prepared for grinding. Black tourmaline was also noted in some masses of this pegmatite, but not in quantity to constitute a menace. Beryl is also present in small amount.

The quartz content in the albite pegmatite is greater than is generally found in the better grades of microcline pegmatite and causes the pegmatite to resemble graphic granite. An average sample of this albite pegmatite was analyzed and found to have the following composition:

Composition of albite pegmatite from Kinkel quarry.

	Per cent.
Ignition loss	0.40
SiO_2	73.88
Al_2O_3	15.73
Fe_2O_3	.36
TiO_2	.01
CaO	.86
MgO	.36
BaO	
K_2O	.48
Na_2O	7.97
	100.05

It has a deformation range of 1,260° to 1,270° C. and it fuses to a pure white enamel.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the albite pegmatite produced a vitreous mass with the peculiar nonmetallic ring when struck, which is characteristic of soda feldspar porcelains.

Fired at 1,330° C. it had a cream-white color by transmitted light, a translucency of 0.78, and a total shrinkage of 11.8 per cent. The porcelain had an excellent color but possessed a slight vesicular structure and was slightly warped, both being evidence of its having been overfired. It also lacked the brilliant fracture of porcelains containing potash feldspars. Under the raw-lead and fritted glazes the color of the porcelain was not altered.

Pure White Albite.

The pure white albite, which occurs in lenses in many parts of this dike, does not constitute a great proportion of the whole, but it must be handled in quarrying, and hence its utilization if practical is important. It is friable and easily crushed in the hand and is generally quite free of associated minerals. In order to remove it without danger of contamination, especial care must be exercised owing to its brittleness. Tests conducted upon average samples of this material indicate that it has a deformation temperature of 1,250° to 1,260° C. and that it fuses to a semitransparent glass.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the pure albite produces vitrification at 1,270° and at 1,330° both warping and vesicular structure are evident. The porcelain is a typical soda feldspar porcelain. At 1,330° C. the total shrinkage is 13.4 per cent and the mass has a cream-white color by transmitted light and a translucency of 0.78. The color of the porcelain is not altered under the raw-lead and fritted glazes.

NORTH CASTLE. HOBBY QUARRY.

The Hobby quarry (69) is located in the town of North Castle on the west bank of Mianus River, and about 1½ miles south of the Kinkel quarry. The quarry is on a steep east slope and is about 150 feet long. The dike is an exceedingly coarse mixture of buff microcline and massive quartz, the quartz constituting more than 50 per cent of the whole. The feldspar is exceptionally free from associate minerals other than quartz, except fine intergrowths of albite. This quarry has not been exhausted but is abandoned.

Samples of the buff feldspar which constitutes the entire feldspar content of this quarry show a deformation range of 1,265° to 1,275° C. and fuse to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,270° C. and at 1,330° C. shows very slight warping. Fired at 1,330° C., it has a cream-white color by transmitted light, a translucency of 0.81, and a total shrinkage of 14 per cent. The color of the porcelain is equal to that the standard trial and is not affected by the raw-lead and fritted glazes.

NORTH CASTLE. BULLOCK QUARRY.

The Bullock quarry (70) is 1½ miles south of the Kinkel quarry and one-half mile west of the Hobby quarry. The dike where exposed is about 35 feet wide and has been worked for a distance of about 60 feet and to a depth of about 30 feet. It strikes northeast and dips northwest.

At the time this property was inspected, in May, 1913, the exposure indicated a narrowing of the dike and the operator predicted a much reduced production. About 1,000 tons of feldspar free from quartz has been shipped from this quarry.

The dike consists almost entirely of massive buff microcline, the only associate minerals being insignificant quantities of biotite. and black tourmaline and a few scattered "books" of muscovite. Quartz is present only in isolated lenses of sugar quartz. Graphic granite and pegmatite are practically absent.

This feldspar on examination is found to contain a small amount of albite crystallized with the microcline. It has a deformation range of 1,270° to 1,280° C. and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard porcelain mixture made with this feldspar vitrifies at 1,280°, and at 1,330° C. no warping is apparent. Fired at 1,330° C., it has a cream-white color by transmitted light, a translucency of 0.76, and a total shrinkage of 14 per cent. The color is equal to that of the standard trial and does not change under the raw-lead and the fritted glazes.

PENNSYLVANIA.

DELAWARE COUNTY.

DARLINGTON. DARLINGTON QUARRY.

The Darlington quarry (71) is 1 mile northeast of Darlington.

This quarry was opened for feldspar and a shallow pit has been dug into the dike. It was later worked for mica by means of shafts. The workings have been abandoned and the shafts filled with water, hence no opportunity to study the dike is provided. About the entrances to the shafts are heaps of albite pegmatite and a small quantity of buff microcline. The albite pegmatite carries an excessive amount of quartz but the microcline is entirely free from quartz.

The albite pegmatite has a deformation range of 1,300° to 1,305° C., and at 1,310° fuses to a shapeless mass of enamel-like material.

The microcline was sampled and analyzed, showing the following composition:

Composition of microcline from Darlington quarry.

	Per cent.
Ignition loss	0.12
SiO_2	64.70
Al_2O_3	19.60
Fe_2O_3	.03
TiO_2	......
CaO	.05
MgO	......
Na_2O	3.76
K_2O	11.87
	100.13

It has a deformation range of 1,280° to 1,290° C. and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar produces a vitreous mass at 1,290° C. and at 1,330° shows no warpage. Fired at 1,330° C., it has a cream-white color by transmitted light, a translucency of 0.87, and a total shrinkage of 13.4 per cent.

The color is equal to that of the standard trial and is not altered under the raw-lead and fritted glazes.

CHESTER HEIGHTS. CHESTER HEIGHTS QUARRY.

The Chester Heights quarry (72) is one-fourth mile west of the railroad station at Chester Heights and about 50 feet above the railroad.

The dike strikes northeast and dips southeast. It averages 20 feet in width and is exposed in the quarry for a distance of about 160 feet. A large proportion of the dike is an albite pegmatite, but toward the north end of the quarry this is displaced by a buff microcline pegmatite in which the quartz is of the smoky variety. In many places the dike contains streaks of chlorite, and the sorting of the feldspar must be conducted with care in order to eliminate this material and also to insure the complete separation of the buff microcline pegmatite and the white albite pegmatite. In the south end of the quarry the albite pegmatite is considerably altered, resulting in a kaolin-like material, but lacking in plasticity. Small quantities of cream and salmon microcline were noted, but not in commercial quantity. The various constituents of this dike are more or less segregated, thus simplifying quarrying, but the proportions of the different ingredients do not maintain sufficient uniformity to permit of a uniform material being obtained by taking the run of the quarry. The microcline and albite pegmatites were sampled and analyzed, showing the following chemical compositions:

Composition of microcline and of albite pegmatites from Chester Heights quarry.

		Microcline pegmatite.	Albite pegmatite.
Ignition loss	per cent..	0.33	0.42
SiO_2	do....	73.35	74.60
Al_2O_3	do....	14.60	15.66
Fe_2O_3	do....	0.06	0.05
TiO_2	do....	......	......
CaO	do....	0.06	2.75
MgO	do....	......	......
Na_2O	do....	2.00	6.33
K_2O	do....	9.11	0.65
		99.51	100.46

The microcline pegmatite has a deformation range of 1,290° to 1,310° C. and fuses to semitransparent glass of a faint cream tint.

The albite pegmatite has a deformation range of 1,290° to 1,295° and fuses at 1,300° to a shapeless mass of white enamel.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

Microcline.—In the standard mixture the microcline pegmatite vitrifies at 1,300°, and at 1,330° C. does not show warping. Fired at 1,330° it has a total shrinkage of 11.8 per cent, a cream color, and a translucency of 0.86. The color is slightly inferior to that of the standard trial. It is not altered under the raw-lead and fritted glazes.

Albite.—In the standard porcelain mixture the albite pegmatite vitrifies at 1,300°, and at 1,330° shows slight warping. Fired at 1,330° it has a total shrinkage of 10.4 per cent, a cream color, and a translucency of 0.79. The color is a good white, but the porcelain is a characteristic soda-feldspar porcelain and lacks the brilliant fracture of the potash-feldspar porcelains. Under the raw-lead and fritted glazes the color is unaltered.

CHELSEA. BUNTING QUARRY.

Midway between Chelsea and Boothwyn station is the old Bunting quarry (73), which has been abandoned for many years. It is reported as having produced a high grade of potash feldspar, but the exposure shows only low-grade pegmatite.

BOOTHWYN. HALSEY QUARRY.

The Halsey quarry (74) is 1 mile northwest of Boothwyn station, on the west side of the Boothwyn-Chelsea road. This quarry has been worked intermittently for the past 15 years. It never has been a large producer, and the workings cover only an area of about 100 square yards. No work has been done here for several years. The dike consists of a coarsely crystalline pegmatite similar to the Chester Heights quarry. The clean buff pegmatite and pure feldspar has all been removed from the quarry, and only a small amount of mixed pegmatite and some albite pegmatite is in sight.

BOOTHWYN. BOOTHWYN QUARRY.

The Boothwyn quarry (75) is one-half mile west of Boothwyn village, on the Boudwin farm, on the east bank of Naaman Creek. The quarry is now filled with water and continuous pumping would be necessary if operations were resumed. In this quarry, which exposes a dike nearly 40 feet wide, the feldspar is a dark buff microcline pegmatite of which a great part is graphic granite. There is little mica and no black tourmaline present in any of the exposed faces or on the dump heaps. As the quarry was filled with water to a level with the creek bed, a thorough inspection was impossible.

Just west of the creek a small pit on a knoll has exposed a dike of albite pegmatite of good quality and apparently very free from impurity. The opening is, however, too small to prove anything beyond the presence of the albite pegmatite.

The buff microcline was tested and has a range of deformation of from 1,295° to 1,310° and fuses to a semitransparent glass of pale cream tint.

The albite pegmatite was tested and has a deformation range of 1,300° to 1,305° C., and fuses at 1,310° C. into a shapeless mass of opaque white enamel.

In the standard mixture the albite pegmatite vitrifies at 1,310° C. and no warping is noted at 1,330°. Fired at 1,330° it has a total shrinkage of 12.6 per cent and a cream translucency of 0.77. The color of the porcelain is good, but it lacks the brilliancy of fracture of the potash-feldspar porcelains.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture the microcline vitrifies at 1,300°, and at 1,330° C. does not show warping. Fired at 1,330° C. it has a total shrinkage of 12.4 per cent, a cream color, and a translucency of 0.79. The color of the porcelain is not quite equal to that of the standard trial, but is fully up to commercial requirements. It is not altered under the raw-lead and fritted glazes.

ELAM. BRANDYWINE SUMMIT QUARRY.

The Brandywine Summit quarry[a] (76), at Elam, 1½ miles south of Brandywine Summit station, was the largest in Pennsylvania, covering about 4 acres and extending in some places to a depth of 100 feet. This quarry was worked for kaolin on the surface, but the lower levels were unweathered feldspar and were very coarsely crystallized with quartz, yielding a great amount of pure feldspar of a cream to flesh color. The main dike has now been worked out and abandoned and the pits and shafts are filled with water. No graphic granite was reported from the main quarry, but about 300 yards east of this a dike of graphic granite of good quality is being opened. This dike lies quite flat and carries a considerable content of weathered material, but this can easily be removed in quarrying. The more solid condition of the surface material would indicate that fresh feldspar in quantity may be looked for at less depth than in the original quarry. The dike now being worked is not so large as the one formerly worked and may be a stringer of that dike. The feldspar is a mixture of buff and cream microcline with intergrowths of albite and is not of sufficiently coarse crystallization to permit of the elimination of the quartz.

Numerous outcrops of feldspar and pegmatite are noted in the neighborhood, and doubtless this district is capable of producing much more feldspar, although another deposit as large as the original quarry is not looked for.

The graphic granite at the new opening was sampled and tested and shows a deformation range of 1,300° to 1,310° C. It fuses to a slightly milky glass with a faint cream tint.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 70-71.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture this feldspar vitrifies at 1,310°, and at 1,330° shows no warpage. Fired at 1,330° it has a total shrinkage of 12 per cent, a cream color, and a translucency of 0.80. The color of the porcelain is hardly equal to that of the standard trial but is equal to that of the product of commercial feldspar. Under the raw-lead and fritted glazes the color is unaltered.

CHESTER COUNTY.

MENDENHALL. OLD WALKER QUARRY.

The old Walker quarry (77) is about 2 miles east of Mendenhall station. This quarry, which is now abandoned, is 120 feet long, 80 feet wide, and at least 50 feet deep, about 15 feet being under water. White albite pegmatite and a small amount of buff pegmatite show in the walls above the water line, and the dumps contain about equal proportions of these two pegmatites. This quarry is on the east side of the highway, which runs northeast at this point, and is about 40 feet below the floor of the new Walker quarry.

MENDENHALL. NEW WALKER QUARRY.

The new Walker quarry (78) is about 2 miles east of Mendenhall station and 300 yards southwest of the old Walker quarry. This quarry is on the west side of the highway, which runs through a ravine at this point, and is opened at a level about 50 feet above the road. It is in a dike about 25 feet wide which consists of a coarse mixture of pure buff microcline feldspar, buff microcline pegmatite, and white albite pegmatite. The strike follows the face of the hill and is northeast. The dip is about 40°. The upper strata are almost pure buff microcline, the middle strata are buff microcline pegmatite, and the lower strata are white albite pegmatite. The quartz in the pegmatites is clear, but the deposit contains many lenses of granular smoky quartz. Muscovite in large and small "books" is very common, and to insure its elimination careful sorting would be necessary. Very little biotite or garnet and no tourmaline were noted in this quarry, which when inspected was 25 feet deep and 50 feet long.

The buff microcline of the pegmatite and the pure buff feldspar were tested and found to possess the same physical properties. The pure buff microcline has the following composition.

Composition of pure buff microcline from new Walker quarry.

	Per cent.
Ignition loss	0.21
SiO_2	64.36
Al_2O_3	20.01
Fe_2O_3	.20
TiO_2	......
CaO	.46
MgO	......
Na_2O	2.48
K_2O	12.44
	100.16

It has a deformation range of 1,280° to 1,295° C. and fuses to a semitransparent glass free from tint.

The albite pegmatite was sampled and analyzed, showing a composition as follows:

Composition of albite pegmatite from new Walker quarry.

	Per cent.
Ignition loss	0.60
SiO_2	67.93
Al_2O_3	20.49
Fe_2O_3	.30
TiO_2	.....
CaO	2.60
MgO	......
Na_2O	6.95
K_2O	.80
	99.67

It has a deformation range of 1,300° to 1,305° C. and at 1,310° C. is fused into a shapeless mass of white enamel.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

Microcline.—In the standard porcelain mixture the buff microcline feldspar vitrifies at 1,300° C. and at 1,330° shows no warpage. Fired at 1,330° C. the total shrinkage is 12.8 per cent, the color is cream white, and the translucency is 0.80. The color is about equal to that of the standard trial and is not altered under the raw-lead and fritted glazes.

Albite pegmatite.—In the standard porcelain mixture the albite pegmatite vitrifies at 1,310° and slightly warps at 1,330° C. Fired at 1,330° C. the porcelain has a total shrinkage of 11.8 per cent, a cream color by transmitted light, and a translucency of 0.80. It has a good white color but lacks the brilliancy of the potash feldspar porcelains. The color is not altered under the raw-lead and the fritted glazes.

EMBREEVILLE. EMBREEVILLE QUARRY.

The Embreeville quarry (79) is about 100 yards north of the depot at Embreeville. The dike[a] has been opened on a slight eminence and shows on both sides of the pit, which is about 15 feet deep and 30 feet in diameter. The feldspar of this dike is albite, occurring with quartz as a pegmatite. No microcline is exposed, and no work has been done here recently except some sampling which had apparently been done just prior to the inspection of this property.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, p. 67.

This albite pegmatite has a deformation range of 1,280° to 1,285° C. and at 1,290° is fused to a shapeless mass of white enamel.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture the albite pegmatite vitrifies at 1,290° and at 1,330° C. shows slight warping. Fired at 1,330° this porcelain has a total shrinkage of 12.2 per cent, a cream color by transmitted light, and a translucency of 0.78. The color is a good white, but the structure shows slight bloating. The raw-lead and fritted glazes do not alter the color of the ware.

NEW GARDEN. LAFFERTY QUARRY.

The Lafferty quarry (80) is 2 miles southeast of New Garden on the Wilmington Pike. The quarry is located within a few rods of the Maryland State line. The dike here is about 30 feet wide and has been exposed to a depth of about 20 feet and for a distance of about 40 feet. The chief constituent of the dike is a pegmatite consisting of light cream microcline and clear quartz, and generally occurring as a finely crystalline graphic granite. Insignificant amounts of albite pegmatite were noted along the walls. The quarry is remarkably free from biotite and garnets, a small amount of muscovite being the only associate mineral noted in the pegmatite. Numerous outcrops of similar microcline pegmatite were noted in the vicinity of this quarry.

The graphic granite in the quarry was sampled and is found by analysis to have the following chemical composition:

Composition of graphic granite from Lafferty quarry.

	Per cent.
Ignition loss	0.30
SiO_2	72.39
Al_2O_3	15.57
Fe_2O_3	.20
TiO_2	......
CaO	.13
MgO	......
Na_2O	2.27
K_2O	9.55
	100.41

It has a deformation range of 1,290° to 1,310° C. and fuses to a semitransparent mass with a faint cream tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the feldspar vitrifies at 1,300° C. and at 1,330° shows no warping. Fired at 1,330° C. the porcelain has a total shrinkage of 11.8 per cent, a cream white color, and a translucency of 0.78. The color of the porcelain is almost equal to that of the standard trial and does not alter under the raw-lead and fritted glazes.

POMEROY. MEREDITH QUARRY.

The Meredith quarry (81) is 1¼ miles northeast of Sadsburyville and 2½ miles north of Pomeroy. The deposit[a] is a dike of varying width, averaging about 15 feet. It is badly folded in places and the strike is uncertain, but has a general northeast direction; the dip is east. The feldspar content of this dike varies in color but is very uniform in physical properties. The upper part of the dike is chiefly a flesh-colored microcline graphic granite of very fine grain. The color of the feldspar fades with depth and becomes practically white. The quartz content of this graphic granite is colorless and perfectly transparent. At a depth of about 25 feet lenses of pure feldspar of a pale cream color were observed at several points in the quarry. At the time of visiting, the workings were about 200 by 60 feet and had a maximum depth of 35 feet. Biotite and tourmaline are extremely rare in this quarry. A green mica is the chief associate mineral and in a few places in the deposits is so abundant that its elimination is not practical. The quantity of feldspar rendered useless on account of the presence of this mica is, however, not sufficient to seriously interfere with mining. This quarry was formerly operated for pottery feldspar but for several years the entire output has been crushed and sold as poultry grit.

The graphic granite of this quarry was sampled and analyzed and shows the following chemical composition:

Composition of graphic granite from Meredith quarry.

	Per cent.
Ignition loss	0.24
SiO_2	67.87
Al_2O_3	17.82
Fe_2O_3	.15
TiO_2	.....
CaO	.12
MgO	......
Na_2O	3.33
K_2O	10.93
	100.46

This graphic granite has a deformation range of 1,285° to 1,300° C. and fuses to a glass which is almost transparent, and has only a faint cream tint.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, p. 67.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture this feldspar vitrifies at 1,290° and at 1,330° C. no warping is apparent. Fired at 1,330° C. the total shrinkage is 11.6 per cent, the porcelain has a light cream color, and a translucency of 0.84.

The color of the porcelain is almost equal to that of the standard trial and is not altered under the raw-lead and the fritted glazes.

CHATHAM. CHATHAM QUARRY.

The Chatham quarry is three-fourths of a mile northeast of Chatham village. The deposit (82)[a] is a pegmatite of very irregular structure but containing chiefly a pale flesh-colored microcline intergrown with white quartz. Small flakes of muscovite and biotite are scattered through some parts of this dike, whereas other parts are practically free from mica. Much massive sugar quartz and very little of the albite pegmatite is noted. A pit approximately 100 by 100 feet and more than 40 feet deep has been opened, but the dike lies very flat here and the overburden increases so rapidly with depth that tunneling was resorted to in order to reduce mining expense. This also was found impracticable and operations have been suspended. Owing to the pit being partly filled with water a satisfactory sampling of this deposit was impossible. An average sample of the feldspar exposed in the walls and found in the dumps has a deformation range of 1,300° to 1,315° C. and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,310° C. and shows no warping at 1,330° C. Fired at 1,330° C. the porcelain has a total shrinkage of 12.6 per cent, a cream color by transmitted light, and a translucency of 0.79. The color of the porcelain is almost equal to that of the standard trial and is fully equal to that of commercial porcelain. It is not altered under the raw-lead and fritted glazes.

TOUGHKENAMON. JENKINS QUARRY.

The Jenkins quarry is 1¼ miles north of Toughkenamon. The deposit (83) is a dike which strikes east and west and dips southeast. The quarry is on a north slope and exposes the dike for a distance of about 50 feet. The feldspar is chiefly coarse buff and salmon microcline pegmatite, with a small quantity of white albite pegmatite. Very little massive quartz is noted. The chief impurities are the micas. The albite pegmatite contains small flakes both of muscovite and of biotite, whereas only muscovite is noted in the microcline pegmatite, and it is confined to limited zones. This quarry was inactive at the time of visiting. The microcline pegmatite was sampled and tested. It has a deformation range of 1,280° to 1,295° C. and fuses to a semitransparent mass with a faint yellow tint.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 65-66.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the microcline pegmatite vitrifies at 1,290° C. and at 1,330°, no warping is apparent. Fired at 1,330° C. it has a total shrinkage of 11.2 per cent, a cream color, and a translucency of 0.85. The color of the porcelain is slightly inferior to that of the standard trial and is not altered by application of the raw-lead and fritted glazes.

TOUGHKENAMON. CARPENTER QUARRY.

The Carpenter quarry (84) is 1½ miles north of Toughkenamon and just west of the Jenkins quarry. The deposit[a] is a dike which at this point is about 30 feet wide and has a north and south strike. Numerous stringers from this dike have been located and the pegmatite removed from them. The main deposit and the adjacent stringers have been worked out for several years, and at present the operation consists of forking over the dump heaps from the original workings. In this way a considerable amount of marketable pegmatite is obtained. The pegmatite of the main dike is reported as being a very coarse mixture of microcline and quartz, but the few stringers exposed in this neighborhood indicate a fine-grained pegmatite, carrying a small amount of albite. Biotite is practically absent and muscovite is present chiefly as small flakes intimately intermixed in the pegmatite.

The microcline pegmatite was tested and found to have a deformation range of 1,275° to 1,290° C. and fuses to a semitransparent mass of a pronounced cream color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture the pegmatite vitrifies at 1,290° C. and at 1,330° C. shows no warping. Fired at 1,330° C. it has a total shrinkage of 11 per cent, a cream color by transmitted light, and a translucency of 0.75. The color of the porcelain is slightly inferior to that of the standard trial, and it is not altered under the raw-lead and fritted glazes.

BAKER. THOMPSON QUARRY.

The Thompson quarry[b] (85) is located three-quarters of a mile east of Baker station and 1½ miles northwest of Avondale. Operations here have been abandoned and no evidence of feldspathic material is visible, except small lumps of very clean microcline pegmatite in the dumps. This pegmatite is practically free from biotite and the muscovite present is confined to lumps of gneiss, which constitute a proportion of the dike about equal to that of the feldspar.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the United States: Bull. 420, U. S. Geol. Survey, 1910, p. 66.

[b] See Bastin, E. S., Op. cit., p. 65.

AVONDALE. HICKS QUARRY.

The Hicks quarry (86) is located 2 miles north of Avondale and almost due north of the Thompson quarry. Narrow dikes with a general north and south strike have been opened by shallow pits, showing a semiweathered albite pegmatite and a solid microcline pegmatite in about equal quantity. Only a few tons of material have been removed and no work was being done at the time of inspection. Both the albite and the microcline pegmatite are contaminated by small flakes of biotite, but the exposures are merely in the capping of the dikes and can not be taken as indicative of the composition of the dike at greater depths. The microcline pegmatite is composed of a mixture of buff and salmon feldspar and gray quartz, and a sample of this pegmatite was taken. It could not be cleaned of its biotite content but was tested for deformation range, which was found to be 1,285° to 1,290° C. The impurity present produces on fusion a yellow glass containing a large amount of undissolved biotite.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture this pegmatite produces vitrification at 1,290° and at 1,330° C. shows no warpage. The total shrinkage is 11.2 per cent and the translucency is 0.59. The color of the porcelain is faulty, due to the biotite present in the ground feldspar.

BAKER STATION. FELDSPAR QUARRIES.

These quarries (87) are located on the property of the Pennsylvania Marble & Granite Co.[a] and on adjacent property [b] at Baker station. The deposit is a dike of varying width but never exceeding 25 feet and is composed of a fine-grained pegmatite intermixed with a gneiss in about equal parts. Both muscovite and biotite are present and render part of the pegmatite worthless. There are three openings but none of them have been operated for several years.

The feldspar content of the pegmatite is a cream microcline with intergrowths of albite in amount equal to the microcline. A considerable quantity of this pegmatite remains at the side of the largest pit, and this was sampled and tested. It has a deformation range of 1,270° to 1,280° and fuses to a semiopaque slightly creamy mass.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the above feldspar vitrifies at 1,280° C. and shows distinct warpage at 1,330° C. Fired at 1,330° C. the total shrinkage is 11.6 per cent, the translucency is 0.74, and the color is cream. The color of the porcelain is slightly inferior to that of the standard trial and is not altered by the raw-lead and the fritted glazes.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, p. 64.

[b] See Bastin, E. S., Op. cit, p. 65.

AVONDALE. COOPER QUARRIES.

The Cooper quarries (88) are 1 mile southwest of New Garden post office and 1½ miles southeast of Avondale. Two quarries have been opened on the property about 400 yards apart. The structure is similar in these pits and as they are on the strike of the dike, which is north and south, they doubtless represent two lenses in the same dike. Both exposures show a pink microcline pegmatite containing smoky quartz and remarkably free from biotite or other iron-bearing impurity. Muscovite is present in very limited quantity. A white albite pegmatite is present but is confined to the regions along the walls of the dikes. The dike at both quarries is about 20 feet wide and has been opened for a distance of about 30 feet in each case. The south pit has been abandoned for some time and is partly filled by the caving of the walls. The north pit has been worked recently and much good feldspar is in sight. The pink microcline pegmatite of this pit was carefully sampled and tested. It has a deformation range of 1,280° to 1,295° and fuses to a semi-transparent glass of a faint cream color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this pegmatite vitrifies at 1,290° C. and at 1,330° C. shows no warpage. Fired at 1,330° C. the total shrinkage is 12 per cent, the color is cream by transmitted light, and the translucency is 0.72. The color is slightly inferior to that of the standard trial and is unaltered under the raw-lead and fritted glazes.

SYLMAR. BRANDYWINE QUARRY.

A number of quarries,[a] of which the majority are now abandoned, are located within a radius of 2 miles west and north of Sylmar, Md., in Chester County, Pa., and Cecil County, Md. The largest quarry at present operating is the Brandywine quarry (89), 1 mile north of Sylmar station. It consists of numerous small pits on an irregular and extremely lenticular dike. The deposit has an entirely different structure from any other feldspar deposit thus far described. The mass of the dike is a coarsely crystalline albite, free from quartz and containing a few isolated crystals of muscovite and hornblende. The walls of the dike contain at frequent intervals narrow bands of a hydrated magnesium aluminum silicate. The dike here has a width of about 20 feet and has been in several places opened for a distance of about 100 feet. There is no variation with depth as is the case in most pegmatite dikes carrying potash feldspars, and quarrying has continued for a depth of 60 to 80 feet which in this narrow dike makes the problem one of shafting rather than quarrying. The albite occurs in three forms—(*a*) as lenses of milk-white, massive rock of concoidal fracture, (*b*) as lenses of cream-colored rock of irregular fracture, and (*c*) as a granular gray rock consisting of semiopaque crystals of albite. The milk-white and the cream-colored rocks constitute the majority of the deposit. All these albites become pure white on calcining, which is a treatment to which all soda feldspar is subjected before grinding.

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[a] For a description of these deposits see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 68-70.

The milk-white and cream albite was carefully sampled and analyzed, showing the following chemical composition:

Composition of albite from Brandywine quarry.

	Per cent.
Ignition loss	0.83
SiO_2	67.47
Al_2O_3	20.05
Fe_2O_3	.15
TiO_2	
CaO	.24
MgO	
Na_2O	9.74
K_2O	.86
	99.34

This albite has a deformation range of 1,270° to 1,280° C. and fuses to a semitransparent glass free from tint at 1,290° C.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280° and at 1,330° C. produces slight warpage. Fired at 1,330° C. the total shrinkage is 12 per cent, the translucency is 0.82, and the color is cream white. The porcelain is almost equal to the standard trial as regards color, but on being struck it gives off a dull sound typical of soda feldspar porcelains.

The magnesium aluminum silicate which occurs along the walls of this dike has the following composition:

Composition of magnesium aluminum silicate.

	Per cent.
Ignition loss	17.30
SiO_2	45.46
Al_2O_3	13.40
Fe_2O_3	.05
TiO_2	.04
CaO	.08
MgO	23.28
Na_2O	.16
K_2O	.30
	100.07

This mineral is crystalline in character and on calcination becomes a pure white. That it has been employed to some extent or at least not eliminated from the albite in the sorting process is evidenced by the fact that analysis of the commercial feldspars of this region invariably show a content of MgO, which according to the analysis given above is not present in either the milk-white or cream albite of this district.

SYLMAR. NEW BRANDYWINE QUARRY.

About one-half mile southwest of quarry (89), the same company has just opened a new quarry (90) on a number of small stringers of the main deposits which are one-fourth mile west. These stringers are only 6 to 10 feet wide where opened, but may expand toward the west. Only the surface has been removed but the material exposed appears similar in every way to that of the formation described above.

SYLMAR. OLD BRANDYWINE QUARRY.

The old Brandywine quarry (91) one-fourth mile west of quarry (90) of this company and 1½ miles by road northwest of Sylmar. This quarry, which is now abandoned and is reported as exhausted, was an enormous lens of albite similar to that found in the smaller dikes now being worked to the east of this quarry. Bastin[a] describes this deposit as a single dike striking northwest and exposed for a distance of 200 feet to a depth of about 80 feet. The dike expands from a width of 12 feet at the south end to about 80 feet at the north end. The wall rock is serpentine with a band of blue-green slate about 1 foot thick along the wall contacts. This quarry was entirely filled with water and no inspection was possible.

SYLMAR. OLD KEYSTONE QUARRY.

The old Keystone quarry (92) is about one-half mile south of the old Brandywine quarry and almost due west from Sylmar station. This quarry is abandoned; the deposit, reported to be exhausted, was an enormous lens similar in all respects to the old Brandywine quarry. The pit, which was reported to be filled with water to depth of 80 feet, is approximately 400 feet long and 150 feet wide. The feldspar mined is reported as similar to that mined in the Brandywine quarry.

SYLMAR. OLD SPARVETTA QUARRY.

The old Sparvetta quarry is located about 300 yards northwest of the old Keystone quarry on what was doubtless the same dike but another lens. The pit, which has filled with water, has a surface area of 500 feet by 150 feet. This quarry produced an enormous quantity of albite of a quality not differing widely from that obtained from the other quarries in the immediate neighborhood.

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[a] Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, p. 69.

MARYLAND.

CECIL COUNTY.

CONOWINGO. ROCK SPRING QUARRY.

The Rock Spring quarry (93), is about 3½ miles northeast of Conowingo, near the village of Rock Springs. This quarry was reported by Bastin[a] as a small operation and has now been abandoned for several years. No evidence of commercial feldspar is to be seen, as the pit has filled by cavings from the walls, thus covering the walls. The feldspar mined was a fine grade of albite, but the quantity obtained is reported too small to justify operations.

CONOWINGO. BALD FRIAR QUARRY.

The Bald Friar quarry (94) is located on a steep bluff on the east side of the Susquehanna River at Bald Friar, 1½ miles north of Conowingo. The feldspar occurs here in a series of sharply defined dikes 6 to 12 feet wide and varying from 25 to 100 feet long. The dike material is chiefly talc, with small lenses of pure white albite of excellent quality occurring at frequent intervals. No quartz, mica, or hornblende was encountered in mining this material. The talc has been exhausted, and the small amount of feldspar still exposed would not justify mining.

This feldspar was tested and found to have a deformation range of 1,270° to 1,280° C. At fuses at 1,290° C. to a semitransparent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this albite vitrifies at 1,280° C., and at 1,330° C. shows slight warpage. Fired at 1,330° C. the total shrinkage is 12.4 per cent and the color is cream white and the translucency is 0.82. The color of the porcelain is excellent, but the structure is distinctly vesicular and the absence of the potash feldspar is evident.

BALTIMORE COUNTY.

GRANITE. GIFFORD QUARRY.

The Gifford quarry (99) is located on the south side of the branch of the Baltimore & Ohio Railroad which runs to Granite, and is 1 mile from the main line. The quarry is in a dike about 30 feet wide, which is composed of a mixture of buff and pale cream pegmatite. Both are microcline pegmatites but the buff is present in by far the largest quantity. A small amount of salmon microcline pegmatite is also observed, but does not constitute an important proportion of the output. The only associate minerals are muscovite and biotite, which are present in small flakes and in small amount only. Most of the mica can be removed by careful sorting.

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[a] Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 76-77.

GRANITE. PEACH QUARRY.

The Peach quarry (100) is on the north side of the branch of the Baltimore & Ohio Railroad leading to Granite, and one-half mile from the main line. This quarry is in a dike very similar to that in which the Gifford quarry is opened. A small amount of muscovite and biotite are noted but no large crystals of either are exposed in this quarry. Numerous small dikes or stringers from the main dikes of the Peach and Gifford quarries have been worked for pegmatite in this immediate vicinity and a product similar to that of the main dikes is obtained. The two large quarries were the only ones operating at the time of visiting.

A sample which is representative of the pegmatite of the dikes along the Granite branch of the Baltimore & Ohio Railroad shows a deformation range of 1,290° to 1,310° C. and fuses to a semitransparent glass with a faint cream tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture, this pegmatite vitrifies at 1,300° C. and at 1,330° C. shows no warpage. Fired at 1,330° C. it has a total shrinkage of 13.2 per cent, a cream color by transmitted light, and a translucency of 0.79. The color of the porcelain is slightly creamy as compared with that of the standard trial, and is not affected by the raw lead and fritted glazes.

DAVIS. DIETZ QUARRY.

The Dietz quarry (102) is one-half mile east of Davis and 150 yards north of the railroad, between Davis and Dorseys Run. This quarry is newly opened, and at the time the writer visited it only the surface material had been removed. The dike, which is about 30 feet wide, was exposed for about 50 feet along the strike, which is northeast. The dike material is chiefly a buff microline pegmatite with minor quantities of albite pegmatite. The associated minerals are massive quartz, in very small amount, and muscovite, also in very small amount only. Biotite or other iron-bearing minerals have not been exposed in sufficient quantity to make their removal a serious problem.

The buff microcline pegmatite was sampled and tested. It has a deformation range of 1,275° to 1,290° C. and fuses to a pale cream glass which is semitransparent.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this pegmatite vitrifies at 1,280° C. and at 1,330° C. shows slight warpage. Fired at 1,330° C. the porcelain has a total shrinkage of 12.4 per cent, a cream color by transmitted light, and a translucency of 0.83. The porcelain shows a slight cream tint in comparison with the standard trial, but this is not intensified by the application of either the raw-lead or the fritted glaze.

ILCHESTER. ILCHESTER QUARRY.

The Ilchester quarry (104) is located on the hill opposite Ilchester. The deposit is a weathered dike in which one of the constituents, a dark buff microcline pegmatite, has withstood the disintegrating action. The rest of the dike has been reduced to a coarse sand, and the solid part is separated by forking or by screening the dike material. There are a number of these dikes in this vicinity, and they all strike northeast. The solid pegmatite is only found in the upper parts of the dike, the material below a depth of 7 feet being completely weathered.

Small flakes of muscovite and biotite are scattered through the pegmatite, but not in large amount. The dark buff pegmatite was tested and found to have a deformation range of 1,290° to 1,305° C. It fuses to a yellow glass which is semitransparent.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this pegmatite vitrifies at 1,300° C. and at 1,330° C. shows slight warping. Fired at 1,330° C. the porcelain has a total shrinkage of 13 per cent, a pronounced yellow color, and a translucency of 0.74. The color of the porcelain is a pronounced cream and becomes yellow under the raw-lead and the fritted glazes.

HOWARD COUNTY.

MARRIOTTSVILLE. ZEPP QUARRY.

The Zepp quarry (95) is one-half mile south of the depot at Marriottsville. This quarry is in a dike, the width of which could not be determined, but from indications is not less than 50 feet. It has been proved for a distance of one-half mile north and prospect pits indicate the presence of what is probably the same dike about one-half mile south.

This quarry was just opened at the time of inspection and much surface material was still to be removed before the extent of the deposit would be exposed. The rock uncovered is a light cream pegmatite, chiefly microcline and quartz, with small intergrowths of albite. Biotite is observed, but this can be removed by careful sorting at the quarry.

MARRIOTTSVILLE. WARFIELD QUARRY.

The Warfield quarry (96) adjoins the Zepp quarry on the north and is on the same dike. This quarry has been opened longer and a better opportunity to study and sample the deposit was afforded. The dike, which was exposed for a distance of 100 feet and a width of about 30 feet, extends under the highway; hence the full width can not be worked. The dip follows the slope of the hillside and is northwest. The feldspar is a cream-colored microline pegmatite, with which is associated a small amount of albite. This dike contains very little biotite, but a band of sandstone and a narrow band of limestone show in the quarry. The limestone and sandstone are easily removed, however, and need cause no contamination in mining. Massive quartz is not encountered in any quantity in this dike so far as exposed.

The pegmatite in this dike was sampled and analysis shows the composition to be as follows:

Composition of pegmatite from Warfield quarry.

	Per cent.
Ignition loss	0.39
SiO_2	65.83
Al_2O_3	19.48
Fe_2O_3	.20
TiO_2	.00
CaO	.00
MgO	.00
Na_2O	1.87
K_2O	11.33
	99.10

This feldspar has a deformation range of 1,295° to 1,310° C. and fuses to a semitransparent glass with a pale cream tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,300° C. and at 1,330° C. shows no evidence of fusion. Fired at 1,330° C. it has a total shrinkage of 12.2 per cent, a cream color by transmitted light, and a translucency of 0.80.

The color of the porcelain is slightly more creamy than that of the standard trial and does not alter under the raw lead and fritted glazes.

MARRIOTTSVILLE. OLD WARFIELD QUARRY.

The Old Warfield quarry (97) is due north from the new Warfield quarry, but is on the opposite side of the creek. This quarry was a good producer of pegmatite similar to that of the new quarry and an opening 30 feet wide and 20 feet deep has been made. The overburden is much heavier than in the new workings and the quarry has been temporarily abandoned in favor of the new quarry, which has only a thin overburden.

MARRIOTTSVILLE. BAKER QUARRY.

The Baker quarry (98), is one-fourth mile east of the depot at Marriottsville, and is located on a steep slope on the south side of the railroad. The opening is about 20 feet in diameter and varies from 5 to 10 feet in depth. The pegmatite exposed is similar to that of the Zepp and Warfield quarries. The only iron-bearing impurity in the pegmatite is a small quantity of biotite which could easily be eliminated without serious loss of feldspar.

MARRIOTTSVILLE. FRENCH QUARRY.

Located about 1 mile northeast of Marriottsville is a small quarry similar to the others in this neighborhood. In this quarry, however, a considerable amount of graphic granite is exposed. Muscovite is practically absent and biotite is present only in very small quantity. This quarry has not been operated for some time, but the deposit is not exhausted.

WOODSTOCK. CAVEY QUARRY.

The Cavey quarry (101) is three-fourths mile south of Woodstock. This quarry exposes two dikes; one is a light buff pegmatite dike of very solid structure, and the other, at least as far as opened, is a mixture of fresh and weathered pegmatite, and to the casual observer would resemble a gravel bank, as in the mining the solid feldspar is separated from the weathered material by means of a fork similar to that used in handling coal. The quarry in the solid dike, which is 15 feet wide and is almost vertical, is about 30 feet long and 12 feet deep. The dike consists of a light buff microline pegmatite associated with a friable white albite pegmatite. The chief associate minerals are muscovite and biotite, small flakes of which are scattered through the pegmatite. To separate these minerals from the feldspar would be extremely difficult owing to the small size of the flakes. The amount present, however, is so small that it does not constitute a menace to the feldspar being successfully used for pottery manufacture.

These pegmatites were sampled separately and analyzed, showing the following chemical compositions:

Composition of microcline and albite pegmatite from Cavey quarry.

	Microcline pegmatite.	Albite pegmatite.
Ignition loss........per cent..	0.13	0.76
SiO_2........do....	74.20	65.32
Al_2O_3........do....	14.30	22.00
Fe_2O_3........do....	.20	.21
TiO_2........do....	.00	.00
CaO........do....	.00	3.78
MgO........do....	.00	.00
Na_2O........do....	1.59	6.89
K_2O........do....	9.48	1.06
	99.90	100.02

This microcline pegmatite has a deformation range of 1,295° to 1,310° C. and fuses to a pale cream semitransparent glass.

The albite pegmatite has a deformation range from 1,310° C. to 1,315° C. and at 1,320° becomes a shapeless mass of white enamel.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

Microcline pegmatite.—In the standard porcelain mixture this microcline pegmatite vitrifies at 1,300° C. and at 1,330° C. shows no warpage. Fired at 1,330° C. the porcelain has a total shrinkage of 13 per cent, a cream color, and a translucency of 0.84. The color is slightly more creamy than that of the standard trial and is unaltered under the raw-lead and the fritted glazes.

Albite pegmatite.—In the standard porcelain mixture the albite pegmatite virtifies at 1,330° C. and at 1,330° C. shows slight warpage. Fired at 1,330° C. the porcelain has a total shrinkage of 11.2 per cent and a cream color by transmitted light translucency of 0.72. The color of the porcelain is a very pale cream, and it is not altered under the raw-lead and fritted glazes.

The weathered dike produces a dark buff microcline of good quality, but the dike is narrow, and the operator stated that it only continues to a depth of 5 to 7 feet, below which it becomes too impure to justify mining.

ALBERTON. ALBERTON QUARRY.

The Alberton quarry (103) is located on a north slope one-half mile south of Alberton. The quarry consists of a shallow pit about 15 feet wide and 50 feet long extending along the face of the hill. The dike material is a buff microcline pegmatite of medium coarse crystallization, with a few lenses of pure feldspar. Muscovite is present in limited zones but not in sizes to make it a marketable product. Biotite is present also, but in small amount. The quarry has only been opened a short time, and the full extent of the deposit is doubtless not exposed. White albite pegmatite is present in such small amount in the present opening as to be negligible.

The buff microcline pegmatite was sampled and tested. It has a deformation range of from 1,285° to 1,300° C. and fuses to a semitransparent glass with a faint cream tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this pegmatite vitrifies at 1,290° C. and at 1,330° C. shows no warpage. Fired at 1,330° C., the porcelain has a total shrinkage of 12.2 per cent, a cream color, and a translucency of 0.76. The color is light cream and is not altered under the raw-lead and fritted glazes.

VIRGINIA.

BEDFORD COUNTY.

LOWRY. M'NICHOLS QUARRY.

The McNichols quarry (105) is located on the Thompson place, 5 miles south of Lowry station, on the east bank of Otter River. There are two dikes exposed on the west slope of a ridge that runs north and south. The dikes' strike is northeast, the dip 75° N. The south dike, where exposed, is about 20 feet wide. In the middle is a band of pure feldspar, varying from 5 to 7 feet wide, with pegmatite on each side. This pegmatite, however, is rich in feldspar, and if care were exercised to eliminate the mica scattered through it much marketable feldspar could be obtained. This dike is opened 25 feet into the hill, being exposed for a depth of 40 feet and across its full width. The north dike, which is separated from the south one by about 30 feet of country rock, shows no band of pure feldspar, but is very rich in feldspar throughout its width of about 10 feet. This pegmatite is very coarsely crystalline and has considerable coarse muscovite scattered through it. Very little material has been removed from this part.

Another exposure of what is probably one of the same dikes is about 150 yards northeast, where pegmatite is exposed for a distance of over 50 feet. This area has not been opened, and the capping material shows muscovite and some biotite. Small lenses of pure muscovite and albite are noted at frequent intervals.

Feldspar from the south dike was analyzed and shows the following chemical composition:

Composition of feldspar from south dike.

	Per cent.
H_2O	0.10
SiO_2	68.75
Al_2O_3	18.56
Fe_2O_3	.03
TiO_2	Trace.
CaO	1.25
MgO	Trace.
K_2O	6.85
Na_2O	4.29
	99.83

The deformation temperature ranges from 1,260° to 1,265° C. The fused feldspar forms an opaque white mass.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

This feldspar in the standard mixture vitrifies at 1,265° C., and at 1,350° C. shows slight warping. The porcelain shows a very faint bluish tint. Fired at 1,350° C. this feldspar has a translucency of 0.64 and is cream colored by transmitted light. The total shrinkage is 15 per cent, the drying shrinkage being 3 per cent and the firing shrinkage 12 per cent. Under the raw lead and fritted glazes the color is unaltered.

NELSON COUNTY.

ARRINGTON. AMERICAN RUTILE QUARRY.

The American rutile quarry (106) is 8 miles northwest of Arrington, near Roseland post office. The quarry is in a dike about 75 feet wide, which has a northeast strike and is vertical. The dike is divided into two distinct sections by a vertical band of trap rock about 20 feet wide. South of this band the dike consists of a plagioclase carrying a high content of rutile and ilmenite. This part of the deposit is worked and the rutile extracted by means of jigs. No attempt to completely extract the ilmenite is made and a considerable amount of rutile remains in the tailings. Many lenses of albite free from rutile and other minerals are noted in this part of the dike but no attempt to save the albite is made, as the haul is too far to make marketing it profitable.

The part north of the trap rock band is similar to the south part, except that hornblende has replaced the other minerals to a considerable extent. If transportation facilities are provided for the development of this property, the associated minerals can doubtless be eliminated from this feldspar and the latter made marketable. The run of the tailings from the south part of the dike has a deformation range of 1,310° to 1,320° C. and fuses to a yellow brown glass.

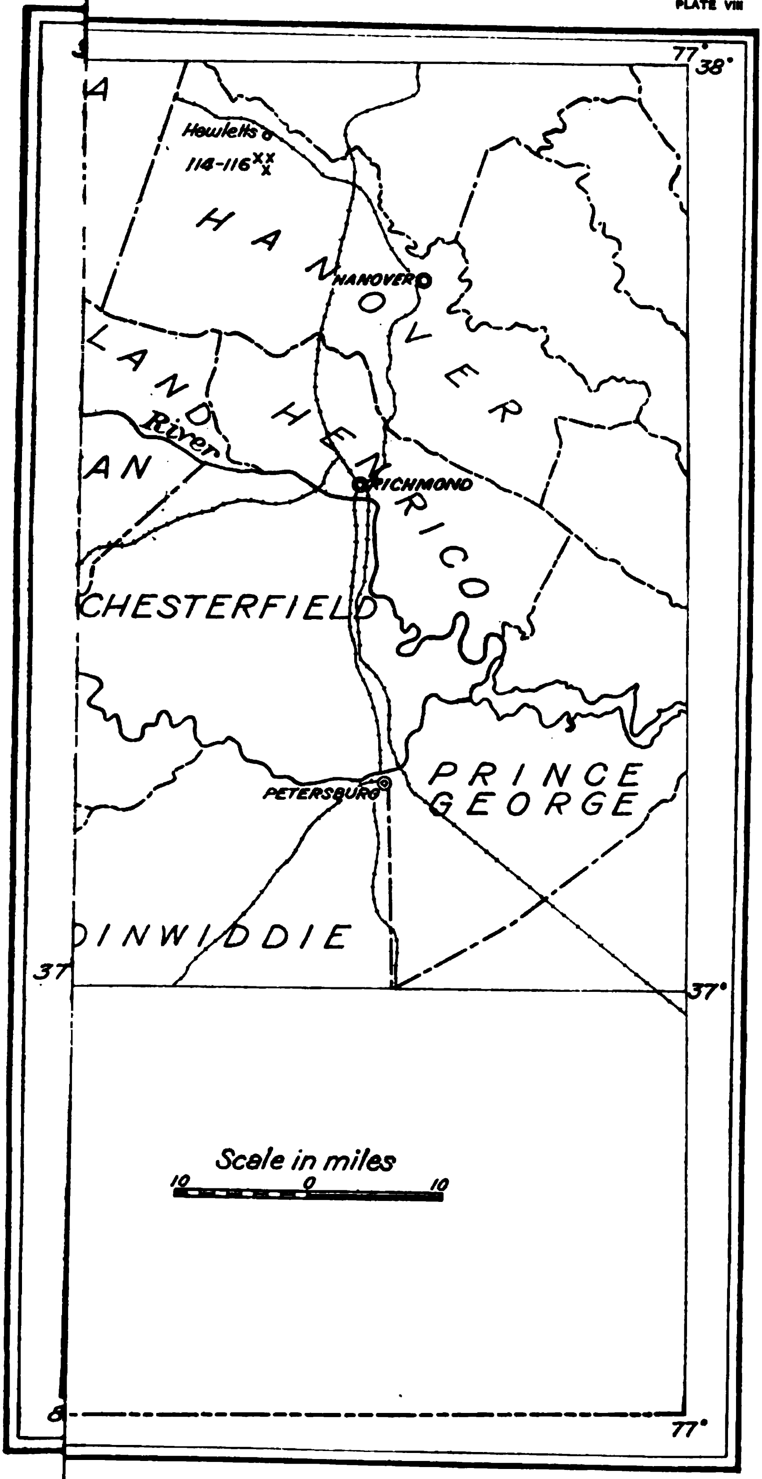
PRINCE EDWARD COUNTY.

PROSPECT. PROSPECT QUARRY.

The Prospect quarry (107) is one-half mile south of the village of Prospect. Two dikes have been opened on this property. One has a width of about 20 feet and has been quarried for a distance of 40 feet and to a depth of 15 feet. The other is about 12 feet wide and has been quarried for a distance of 30 feet and to a depth of about 12 feet. A large part of these dikes is a light cream pegmatite containing an excessive amount of quartz and also a large amount of muscovite distributed throughout the mass as small flakes. This part of the dike is, therefore, of doubtful value for pottery feldspar. Lenses of buff microcline pegmatite and lenses of pure buff microcline are present in large amount in both dikes. In the large dike one lens 8 feet wide is exposed. This buff microcline and pegmatite is very low in muscovite content and the pegmatite is low in quartz. No biotite is observed in either of the dikes, and other iron-bearing minerals are absent also. Operations on this property have been intermittent and the quarry was idle at the time of inspection. The dikes have not been exhausted, however.

The buff microcline and pegmatite were sampled to obtain an average of the run of the quarry and this was found to have a deformation range of 1,295° to 1,310° C. It fuses to a pale cream semitransparent glass.

PLATE VIII



ABLE 2.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this material vitrifies at 1,300° C., and at 1,330° C. no warpage is apparent. Fired at 1,330° C. this porcelain has a total shrinkage of 13.4 per cent, a cream color by transmitted light, and a translucency of 0.74. The color is slightly cream when compared with that of the standard trial, and is unaltered under the raw-lead and the fritted glazes.

AMELIA COUNTY.

JETERSVILLE. OLD SCHLEGEL QUARRY.

The old Schlegel quarry (108) is 1¼ miles northwest of Jetersville. This quarry was opened on a lens of a dike which can be traced for at least one-half mile northeast along the strike. The quarry has a width of about 20 feet and a length of about 40 feet. The workings have caved so that both the walls and the floor are obscured but a narrow face of wall was cleared along the strike and a cream microcline exposed which is free from quartz or other associated impurity. A large quantity of this class of feldspar is reported as being quarried here but a coarse pegmatite constitutes a considerable part of the dike. Numerous small dikes or stringers are noted throughout this country but no attempts have been made to prospect these.

The feldspar samples taken from the old Schlegel quarry were tested and found to have a deformation range of 1,295° to 1,310° C. and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,300° C., and at 1,330° C. shows no warpage. Fired at 1,330° C. the porcelain has a total shrinkage of 13 per cent, a cream-white color by transmitted light, and a translucency of 0.82. The color of the porcelain is equal to that of the standard trial and is not altered under either the raw-lead or the fritted glaze.

An exposure of pegmatite (109) about 20 feet high occurs at Jetersville pond, 2 miles northeast of Jetersville, where the Jetersville-Painesville road crosses Flat Creek.

AMELIA. RUTHERFORD MICA MINE.

The Rutherford mica mine (110) is located 2 miles northeast of Amelia courthouse. The dike here is not exposed as the workings, which consisted of a number of shafts, have filled with water and have caved in many places. The width covered by shafts appears to be about 12 feet and the shafts continued along the strike for about 75 feet. There was no attempt at feldspar mining, so far as could be learned, but the dumps about the shafts contain large quantities of a semitransparent albite of exceptionally fine color, and a brilliant green microcline. Small "books" of a clear muscovite are also plentiful. Quartz is present only in the massive form. The albite appears to constitute the major part of the dike. An average sample of this shows a deformation range of 1,270° to 1,280° C. and at 1,290° C. fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this albite vitrifies at 1,280° C., and at 1,330° C. shows warping. Fired at 1,330° C. this porcelain has a total shrinkage of 12.8 per cent, a cream color by transmitted light, and a translucency of 0.86. The porcelain has a good color but lacks the brilliancy of the potash feldspar porcelain and shows a slightly vesicular structure. The color is not altered under the raw-lead and fritted glazes.

The green microcline is in sharply defined crystals but not in quantity to be economically important. An average sample of this microcline shows a deformation range from 1,280° to 1,295° C. and fuses to a semitransparent mass free from tint.

AMELIA. PINCHBACK MICA MINES.

The Pinchback mica mines (111, 112), which were apparently open pits, are scattered over an area of several acres just north of the Rutherford mine. These pits have all been filled by caving of the walls and by surface material draining into them. No refuse from the workings is exposed in dumps except a small amount of scrap mica. The latter is doubtless scrap or trimmings from the block mica as it is a considerable distance from the pits. No feldspar or quartz is found in the neighborhood of any of the shafts.

AMELIA. OLD CHAMPION MICA MINE.

The old Champion mica mine (113) is 3 miles northeast of the courthouse at Amelia and is east of the Pinchback mines. The dike is reported to be about 12 feet wide and has a general north and south strike and is nearly vertical. This mine was abandoned and allowed to fill with water, but at the time of inspection had been almost completely unwatered, as the mining of mica was to be resumed. The dike, as exposed in the walls of the shaft for a depth of 105 feet, is a coarse mixture of albite pegmatite and gray semiopaque quartz. The albite pegmatite averages about 5 feet wide and the quartz constitutes the remainder of the dike, which was intruded into a biotite gneiss. The muscovite, for which the mine was worked, occurs along the contact of quartz and pegmatite and along the contact of the pegmatite and wall. With the methods of mining practiced here, little of the feldspar will be removed.

The albite was sampled and tested. It has a deformation range of 1,300° to 1,305° C. and at 1,310° C. is completely fused. The presence of considerable calcium is indicated by the high deformation temperature and the rapidity of fusion. The opaque enamellike appearance of the fused feldspar also indicates a high calcium content.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,300° C. and at 1,330° C. shows warping. Fired at 1,330° C. the porcelain has a total shrinkage of 12 per cent, a cream-white color by transmitted light, and a translucency of 0.87. The color of the porcelain is an excellent white, but the texture is vesicular. The color, however, is not affected by the raw lead and fritted glazes.

HANOVER COUNTY.

HEWLETTS. HEWLETTS MICA MINE.

The Hewletts mica mines (114, 115, 116) are 2 miles southeast of Hewletts and 1 mile north of the Washington-Richmond highway. Three quarries were opened on this property about 1870, but the mining was for mica and only such other material was removed as was necessary. The method of mining was by deep open cuts and these are reported to be 50 feet deep in places. Most of the cuts are about 100 feet long and about 8 feet wide. They were partly filled with water and thus an examination was made very difficult. The feldspar present is an albite of remarkable clearness and pronounced crystallization; associated with this is massive quartz, in quantity, which is clear and remarkably free from granulation. No iron-bearing minerals were observed on the dumps or associated with the feldspar and quartz in the exposed parts of the dike. The albite was sampled and tested. It has a deformation range of 1,305° to 1,310° C. and at 1,315° C. is completely fused, forming a white enamellike mass. This albite apparently has a considerable calcium content, as indicated by its high deformation temperature and short range.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,310° C. and at 1,330° C. shows slight warpage. Fired at 1,330° C. the porcelain has a total shrinkage of 11.8 per cent, a cream-white color by transmitted light, and a translucency of 0.75. The color of the porcelain is good, but it has that texture characteristic of soda feldspar porcelains.

HENRY COUNTY.

RIDGEWAY. FELDSPAR DEPOSITS.

All these deposits lie within 2 miles, south and west, of Ridgeway. The feldspar is exposed in a number of places and shows evidence of being present in large quantities. It occurs in pegmatite that varies in fineness of structure, the feldspar content being chiefly cream microcline and ivory albite, associated with gray quartz and pale-green to rum-colored muscovite. Some white sugar quartz is present but in smaller amount than at points farther south. The country rock is chiefly gneiss. The dikes throughout the district have a general northeast strike.

One irregular exposure (117) in the bed of Matrimony Creek, near an old mill on the property of J. P. Garrett, has a breadth across the dike of at least 40 feet. The feldspar-bearing pegmatite is massive in some places and in others is fine grained with much fine mica. The creek flows between high hills and unless the feldspar can be found farther up the hillsides the cost of mining will be excessive because of overburden, except in the bed of the creek, where the problem of handling water would be serious. The deposit is about 2 miles south of Ridgeway and about 1 mile from the railroad.

On the same property, about one-half mile east of 117 in a road is an outcrop (118) of fine-grained pegmatite containing considerable fine mica considerably weathered. The indications are not very encouraging, but more prospecting should be done before any definite statement, regarding either quality or quantity, is made. This exposure is about 2 miles from Ridgeway and about 1 mile from the railroad.

On the same property, about one-half mile northwest of 117 in the bend of a road on a ridge a dike (119) is exposed that is about 50 feet wide but contains a number of bands of gneiss. Both feldspar and gneiss are much weathered in places. Several smaller dikes of completely kaolinized material have been exposed on this same ridge. This deposit is about three-quarters of a mile from the railroad, with a downhill haul.

About one-half mile to the northeast of 117 on the north slope of a ridge, running east-northeast, an extensive deposit of pegmatite has been exposed, either a large dike, containing several bands of included gneiss, or a series of narrower parallel dikes. The exposure has a total width of almost 100 feet and has been proven for a length of 250 feet. The pegmatite exposed is very coarse, containing much massive feldspar. The overburden varies from 5 to 10 feet. This deposit is one-half mile from the railroad, which is reached by a comparatively level haul. It was worked about five years ago and a few carloads shipped for grinding. Difficulties in marketing caused a shutdown.

The deposits on this property were all sampled and tested with the following results:

The feldspar from deposit 117 is a cream microcline pegmatite with intergrowths of albite. Its deformation range is 1,290° to 1,300° C. and it fuses to an excellent white enamel.

The feldspar from deposit No. 118 could not be obtained in sufficient purity to make a satisfactory test.

The feldspar from No. 119 is a cream-colored microline, free from any associated material, except quartz, and muscovite, the latter in small amounts only. It has a deformation range of 1,310° to 1,330° C. and an excellent color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar produces vitrification at 1,300° C., and at 1,330° C. shows no warping. Fired at 1,300° C., it has a total shrinkage of 14.5 per cent and a cream white translucency of 70. The color is not altered by either the raw lead or fritted glaze.

The feldspar from deposit No. 120 is a cream microline similar to that from No. 119, but having a deformation range of 1,305° to 1,330° C. The color is excellent.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

Introduced into the standard porcelain mixture, this feldspar produces vitrification at 1,300° C. At 1,330° C. it showed no warpage, has a total shrinkage of 14.7 per cent, and a cream-white translucency of 72. The color is not altered under either the raw lead or fritted glaze.

RIDGEWAY. RIDGEWAY MICA COMPANY MINES.

This property (120) is one-fourth of a mile northwest of the depot at Ridgeway. The dike which is worked for mica is 5 to 10 feet wide and strikes nearly north. The feldspar is not present in sufficient quantities to make it any considerable asset to the company. It is chiefly a cream microcline. The associated mica is rum-colored muscovite and is very solid.

One-half mile northeast of the mica mine and between the highway and the railroad a dike similar to the one worked for mica has been exposed in a shallow pit. It carries more feldspar but the surface exposures available are badly stained with surface material, preventing a satisfactory sampling. The feldspar shows on both sides of the pit, which is about 8 feet across.

A number of pegmatite dikes more or less weathered are exposed along the line of the railroad in cuts north and south of Ridgeway Station. In most cases weathering is not sufficiently advanced to justify working the deposits for kaolin. The exposures are from 10 to 30 feet wide. Judging from the deeper workings in the mica mines, weathering may not continue to any great depth, and marketable feldspar might be obtained by removing this weathered material.

Much prospecting by shafts and cuts has been done throughout this district and little additional work should prove the quality and quantity of the deposits.

LIST OF FELDSPAR GRINDING MILLS.

The following list is based upon the fullest information obtainable but is not guaranteed to be complete.

FELDSPAR MILLS IN MAINE.

Maine Feldspar Co., Littlefield Station, Androscoggin County.
Maine Feldspar Co., Topsham, Sagadahoc County.
Trenton Flint & Spar Co., Cathance, Sagadahoc County.

These companies grind pegmatite from local quarries for use in making pottery.

FELDSPAR MILLS IN CONNECTICUT.

L. W. Howe, South Glastonbury, Hartford County.
The Wiarda Co., South Glastonbury, Hartford County.

These companies grind pegmatite from local quarries for use in making pottery, glass, and enamel.

The White Rocks Co., Middletown, Middlesex County.

This company crushes pegmatite from local quarries for roofing gravel, poultry grit, and concrete, but makes no pottery material.

FELDSPAR MILLS IN NEW YORK.

Crown Point Feldspar Co., Crown Point, Essex County.
Barrett Mfg. Co., Ticonderoga, Essex County.

These companies crush pegmatite from local quarries for use as roofing material, poultry grit, and stucco facing, but produce no pottery material.

Bedford Feldspar Co., Bedford Village, Westchester County.
P. H. Kinkel Sons, Bedford Village, Westchester County.

These companies grind pegmatite from local quarries for use in making pottery, glass, and enamel.

Pennsylvania Feldspar Co., Barnards, Monroe County.

This company grinds Canadian feldspar, chiefly for pottery purposes. The mill was destroyed by fire in December, 1914, but is being rebuilt.

MILLS IN NEW JERSEY.

Golding Sons Co., Trenton.
Eureka Flint and Spar Co., Trenton.

Both of these companies grind pegmatite from various districts in the United States.

MILLS IN DELAWARE.

Golding Sons Co., Wilmington.

This company grinds pegmatite from various producing districts in the United States.

MILLS IN PENNSYLVANIA.

Brandywine Summit Kaolin and Feldspar Co., Brandywine-Summit, Chester County.

This company grinds soda and potash pegmatite from local quarries.

Pennsylvania Feldspar Co., Toughkenamon, Chester County.

This company grinds Canadian feldspar and Pennsylvania pegmatite.

Meredith Mining & Milling Co., Pomeroy, Chester County.

This company crushes local pegmatite for poultry grit.

MILLS IN OHIO.

Golding Sons Co., East Liverpool.
Potter's Mining & Milling Co., East Liverpool.
This company grinds pegmatite from various districts in the United States.

MILLS IN WEST VIRGINIA.

The Newell Mining & Milling Co., Newell.
This company grinds pegmatite from various districts in the United States.

MILLS IN TENNESSEE.

The Clinchfield Mining & Milling Co., Johnson City.
This company grinds pegmatite from Mitchel and Yancey Counties, N. C.

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Bulletin 93

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FRANKLIN K. LANE, SECRETARY
BUREAU OF MINES
VAN. H. MANNING, DIRECTOR

MINERS' NYSTAGMUS

BY

FREDERICK L. HOFFMAN

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PREFACE.

The prevalence of occupational diseases among miners in the United States is a matter of deep public concern, although it has received little systematic study as yet. The Bureau of Mines is directed by law to undertake investigations looking to the improvement of safety and health conditions in mines and, in cooperation with the Bureau of the Public Health Service, has done a limited amount of work in a few metal-mining districts, chiefly with regard to the prevalence of pulmonary tuberculosis and to the effects of rock dust, made by drilling and blasting, as an exciting cause of diseases of the lungs.

In the absence of broad and detailed studies it is impossible to say whether diseases common among European miners are prevalent in the same relative proportions among miners in the United States. It is to be presumed, however, that those diseases that are induced by specific causes, such as the breathing of fine sharp particles of siliceous rock or work under conditions that tend to strain excessively any organ of the body, will be found to occur in the United States in proportion as these causes are effective. In other words, it is to be expected that, owing to the differences in natural conditions and in mining methods, certain diseases will be found to be more prevalent in one country or in one district than in another.

Miners' nystagmus seems to be widespread in Europe and to be decidedly common in some districts there. As it may prevent a miner from working at his regular task and may even cause prolonged total disability, it is recognized in both England and Germany as properly entitling the sufferer to compensation under the provisions of employers' liability or workmen's insurance laws.

Workmen's compensation laws have been enacted in more than thirty of the States in the United States, and there is widespread interest in the subject of occupational diseases. The Bureau of Mines in its investigations of safety and health conditions in mines is giving attention to the ailments to which miners are particularly subject as a result of their daily work. The following paper on miners' nystagmus has been prepared by Mr. Hoffman, who has given years of study to the morbidity and accident rates of different occupations and is widely known through his writings on occupational accidents and diseases.

As there has been no thorough investigation of miners' nystagmus in the United States, Mr. Hoffman has reviewed the results of investigations in Europe and has drawn some tentative conclusions as to the possible frequency of the disease in this country. Possibly some

American physicians and mining engineers will doubt that many American coal miners are afflicted with nystagmus, and will advance as reason for their opinion the use of undercutting machines in the United States and the lessened amount of undercutting now done with the pick. The use of open-flame lamps in the many nongaseous mines and the increasing use of electric lamps in gaseous mines and the better illumination obtainable by them than by the safety lamps generally used in Europe may be, in the opinion of some engineers, additional reasons for believing that there is less eye strain, the cause of nystagmus, among American than among European coal miners.

Whatever may be the prevalence of nystagmus in the United States, its seriousness as a disease and the need of national and State agencies cooperating in endeavors to obtain exact information regarding it are deemed sufficient reasons for the publication of Mr. Hoffman's interesting and suggestive paper.

VAN. H. MANNING.

MINERS' NYSTAGMUS.

By **Frederick L. Hoffman.**

INTRODUCTION.

Miners' nystagmus is the result of a peculiar form of eyestrain, which often results in impairment of vision and a consequent diminution of the wage-earning capacity of the workman.

Historically it has been pointed out by Shufflebotham[a] that "This disease was first recognized by Gillett, of Sheffield, about 1854, although no case was mentioned in medical literature until 1861, when the symptoms were described by De Conde, a Belgian physician. Cases were reported by Pepp Müller as early as 1860, by Von Graefe in 1873, and by Bell Taylor, of Nottingham, and by Nieden in 1874. In this country (England) we are indebted to a very large extent to the observations and writings of the late Simeon Snell and for his pioneer work on this many-sided disease; in France Dransart occupies a similar position." In the treatise on "The Effects of Arts, Trades, and Professions," by C. Turner Thackrah, published in London in 1832, it is stated that—

> The complexion of the colliers, even after the removal of the dirt, is generally sallow and unhealthy. Their eyes, from the swelling of the lids, appear small, are affected with chronic inflammation and intolerant of full light. * * * Sickness and vomiting sometimes affect persons at their commencing the employ; and many, after a few years' trial, are obliged, by the injury which their health has sustained, and especially by the weakness of their eyes, to leave the mine.

According to Greer,[b] an authority on industrial diseases and accidents, miners' nystagmus occurs in 5 per cent of all miners, but it is quite probable that the reference is to European coal miners rather than to men employed in all branches of the mineral industry. According to the same authority,[c] miners' nystagmus "is associated with a twitching of the eyelids and with considerable diminution of the range of movement of the eyes, and is particularly liable to occur in patients whose vision is subnormal owing to errors of refraction, especially astigmatism. It causes much inconvenience to those suffering from it and prevents them from following their usual occupation as, owing to the movements of the eyes, everything at which they look appears to be in a state of perpetual motion, and in consequence their visual acuity is more or less reduced. When the movements cease the vision becomes as good as it was previously."

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[a] Shufflebotham, Frank, Miners' nystagmus: Brit. Med. Jour., Mar. 21, 1914, p. 648.

[b] Greer, W. J., Industrial diseases and accidents, London, 1909, p. 304.

[c] Greer, W. J., Loc. cit.

Barnett,[a] with reference to the British workmen's compensation act of 1906, states that nystagmus "is a condition often found in miners owing to excessive strain of the eye. The cause of the affection is the constrained position of the eyes, producing chronic weariness. It is usually present in those miners engaged in 'kirving' or bottom-holing a seam of coal; in doing this they have to lie in a very strained position, striking the coal with a horizontal swing of the pick, and having to keep their eyes fixed on one spot, using the elevator muscles constantly."

The symptoms of the affliction are stated by Barnett to be as follows:

> There are usually objects dancing before the eye. There is oscillation of the eyeball, headache is often present, and giddiness sometimes causes the miner to stumble. The movements of the eyeball are rotary and to and fro, rarely vertical; the rapidity of the motion may be great. Tremors of the muscles of the head and face are often associated with the trouble.

SOURCES OF INFORMATION.

The literature on nystagmus is considerable, but is limited chiefly to contributions to medical and mining periodicals. A complete treatise on the subject of miners' nystagmus was published in 1894 at Wiesbaden, by Nieden.[b] There are numerous descriptive accounts of individual cases of miners' nystagmus, most of which confirm the view that the immediately responsible cause for the disease is the defective illumination under which underground mining is frequently carried on. There are other forms of nystagmus, both congenital and hereditary, and some cases of the disease have been reported for men employed in other occupations than mining, including a case of nystagmus in a compositor, reported by Snell[c] in 1890. As pointed out by Thompson,[d] in his recent work on occupational diseases—

> Nystagmus as an occupational symptom is not alone confined to miners, and may develop in those who are compelled to give close visual attention to constantly moving objects. For example, Dr. Collie, of the British factory inspection service, found that 28 per cent of 516 female sewing-machine operatives had slight grades of nystagmus from fatigue of the eye muscles in following the work through the machine. Exceptional cases have occurred among compositors who kept their copy above the eyes and threw the head backward to glance at it.

According to the same authority,[e] the symptom of rapid oscillation of the eyeballs, typical of miners' nystagmus, "is due to picking at overhead coal, which requires strain of the eye muscles, the eyes being constantly directed both upward and to one side. It is therefore limited to those who handle the pick exclusively. The symptom usually subsides in time after the form of work has been changed. It is at present a rare phenomenon, owing to two causes—first, the increasing introduction of machine methods and, secondly, the operation of the gross-weight law, whereby miners are paid for the gross tonnage of the coal mined, not on the basis of the size of the nuggets. When the latter system prevailed the miners sought to increase their earnings by carefully picking out large fragments of coal, which involved the ocular strain."

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[a] Barnett, H. N., Accidental injuries to workmen, London, 1909, p. 133.

[b] Nieden, A., Der Nystagmus der Bergleute, 1894, 140 pp.

[c] Snell, Simeon, Eye diseases and eye accidents in relation to industrial occupations: In "Dangerous Trades," by Thomas Oliver, London, 1902, chap. 58, pp. 761-765.

[d] Thompson, W. G., The occupational diseases; their causation, symptoms, and prevention, 1914, p. 570.

[e] Thompson, W. G., Op. cit., pp. 569-570.

Thompson[a] quotes Browne and Mackenzie to the effect that—

> The contributing factors in producing this symptom are: Inadequate light, errors of refraction, straining of the extrinsic eye muscles, and a neurotic temperament. Ninety per cent of their patients had errors of refraction. The symptom is often attended by severe pains in the head and eyes and by quivering of the eyelids. The miners find some relief from the affection by walking with the eyes directed downward. No special treatment, except rest, is of any avail, and after a prolonged period spontaneous recovery may take place, which may be partial if not always complete.

The following suggestive description of nystagmus is by Louis:[b]

> Probably the most unhealthful part of the coal miner's work consists in "kirving" or undercutting the coal, in doing which the miner has to lie on his side on the floor of the coal seam, swinging his pick with a peculiar sideways stroke over his head, till he has cut out a narrow groove some 3 feet deep below the overhanging mass of coal. Work in this constrained position is necessarily harmful to some extent. Its effect has been most noticed as affecting the nervous system, and especially the nerves of the eyes, the disease known as miner's nystagmus having been often ascribed to it. Cases of miner's nystagmus occur, however, also among miners who do not have to kirve, and it may well be due in great part to the poor light obtainable in so many cases underground, especially when safety lamps are used, and the consequent strain on the eyes. At any rate this seems to be the opinion of several who have suffered from this complaint.

OCCUPATIONAL EYESTRAIN.

In the same work, in connection with a discussion of eye diseases and eye accidents in relation to industrial occupations, Snell,[c] a recognized authority on ophthalmology, contributes an extended discussion on nystagmus, not only among miners, but also among persons employed in other occupations underground. The findings and conclusions of Snell have not been accepted in their entirety by other authorities on the subject of nystagmus, but they are given in full so as to provide the necessary basis for comparison with divergent views subsequently to be quoted.

> Coal miners, as a result of their employment, are especially prone to a peculiar affection of the eyes called "nystagmus" (miners' nystagmus), which is characterized by

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[a] Thompson, W. G., Op. cit., p. 570.

[b] Louis, Henry, Mining: Thomas Oliver's "Dangerous Trades," London, 1902, chap. 37, p. 534.

[c] Snell, Simeon, Eye diseases and eye accidents in relation to industrial occupations: In "Dangerous Trades," by Thomas Oliver, London, 1902, chap. 58, pp. 760-772.

oscillations of the eyeball. The sufferer, too, complains of objects dancing before his eyes. In this disease objects appear to move either in a circle or an ellipse. Headache is often present, and especially giddiness, which sometimes causes the miner so to stumble about that he is compelled to leave his work in the mine. The movements of the eyeball are chiefly rotatory; to-and-fro oscillations are sometimes superadded. These are rarely vertical, but the rotatory are seldom, if ever, absent. The rapidity of the ocular motions varies greatly; from 60 to 150 motions may be counted in a minute. I have observed them as frequent as 350. Both eyes are affected, but the rapidity of movements may vary in the two eyes. The more rapid the oscillations the less extended is the excursion of the globes. The oscillations are arrested by turning the gaze downward below the horizontal line, and miners often learn to rest their eyes in this way. Looking upward, and especially obliquely to one side or the other, rapid movements of the head, lowering of the head, and suddenly raising it are means of increasing the rate of movements of the eyeballs, or, in other cases, of rendering them evident. Placing the patient in the position he would assume at his work is another method. Tremors of the head (noticeable to the hand placed on the head), of the eyelids, and of the muscles of the face or neck are often associated with nystagmus, and so is torticollis or "wry neck" in some cases. Night blindness has been alleged to be present, but there is some reason to dispute this. The nystagmus alone is a sufficient cause for any difficulty in seeing in a failing light. Errors of refraction, myopia, hypermetropia, and astigmatism are often present, but bear no causal relation to nystagmus; visual acuity is generally unaffected. Color perception is good, and, so far as the movements of the eyeballs permit of testing, the field of vision is normal. The onset of the disorder is often brought about by some attack of illness. It is generally met with in men who have worked in the mine for some years. Ninety per cent of cases occur in persons from 25 to 45 years of age.[a]

Nystagmus is found chiefly in miners who work at the coal face in a more or less constrained position of the body and the eyes. The methods of mining in England differ somewhat from those in this country, especially in details that have an important bearing on the occurrence of nystagmus, and therefore it seems appropriate to include a brief abstract from the article of Snell regarding conditions under which nystagmus in English coal mines is most likely to occur. The abstract follows:[b]

It is desirable to get coal in as large pieces as possible, and to do this they undercut or "hole" the seam. A man sits with his legs crooked up, lying almost on his side, and strikes the coal with a horizontal swing of his pick at the bottom of the coal seam. He will cut away the coal to a height of 18 inches to 2 feet, and then as he gets deeper in he will draw his body under the coal, lying on one side or the other. The process is called "holing," and sometimes the undermining may be continued from 2 to 3 feet to as much as 7 or 8 feet; the distance varies considerably. As he proceeds with his work the miner applies timber supports to keep the coal from falling. This just described is called "bottom holing," but the seam may be attacked in the middle (middle holing) or at the top (top holing). A miner engaged at this work will direct his gaze to different parts as it becomes necessary for him to strike, for the eyes will follow the pick point, but the tendency will be for the gaze to be directed upward (using the ocular elevators) more or less obliquely. He will lie sometimes on one side and sometimes on the other. His legs will be crooked up, his head thrown back and flexed more or less on the shoulder beneath. * * * Ninety-eight per cent of all cases of nystagmus coming under my notice have been in men occupied at the coal face and more or less engaged at this kind of work.

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[a] Snell, Simeon, Eye diseases and eye accidents in relation to industrial occupations, in "Dangerous Trades," by Thomas Oliver, London, 1902, chap. 58, pp. 761-762.

[b] Snell, Simeon, Op. cit., pp. 762-763.

NYSTAGMUS A DISEASE OF COAL MINERS.

Regarding other underground occupations liable to nystagmus, the disease appears to be rare among them. Thus, for illustration, overseers whose work requires the inspection of underground conditions, both as regards freedom from gas and the security of the roof of the room or chamber in which the work is being done, suffer occasionally from nystagmus, according to Snell, probably because of the fact that their particular duties necessitate "the same upward and oblique direction of the gaze." He points out, however, in this connection that frequently the men employed as overseers have previously worked as coal miners, and he therefore concludes that, as a rule, all cases of nystagmus occur in those who are either working or have worked as coal miners, or who work in such positions as to require an upward direction of the eye for more or less prolonged periods. He also concludes that the causation of the affection "must be sought in this constrained position of the eyes by which chronic weariness is induced in the elevator muscles of the eyes. Like effects are found in other muscles of the miner, producing wry neck, tremors of the head, and quivering of the eyelids. It is thus similar to other occupational neuroses and in the same category as those found in writers, compositors, telegraphers, and many others."

BEARING OF INSUFFICIENT ILLUMINATION.

As regards the important question of insufficient or imperfect lighting, the opinion is expressed by Snell[a] that nystagmus occurs among miners working with all kinds of lighting, and that he has met with it among those working with safety lamps, candles, large open lamps, as well as when the artificial light was really good. He concludes, however, that there are reasons "for believing that the strain is greater the worse the light, and that nystagmus is met with in greater frequency under such conditions." He quotes Nieden to the effect that 5 per cent of coal miners suffer from nystagmus, and he adds that his own observations support this view, but that in some places the percentage is higher. For illustration, among men working at a colliery with candles only, he found that 6 out of a total of 140 were absent from work on account of nystagmus, and that this represented only a part of those who, on examination, would have shown to have been actually affected with the disorder. Snell[b] quotes Romiée, a Belgian authority, to the effect that the percentage of nystagmus cases was as high as 20, but he adds that this probably includes the less marked cases.

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[a] Snell, Simeon, Op. cit., p. 764.

[b] Snell, Simeon, Op. cit., pp. 760–762.

PROGNOSIS, TREATMENT, AND CURE OF NYSTAGMUS.

The prognosis in nystagmus, according to Snell, is usually good, even for old-standing cases, if the directions as to a change of work are followed, and in such cases the nystagmus will usually disappear. As to treatment, particularly with reference to a change of occupation, Snell[a] points out that—

> In some cases it will suffice if the patient ceases from coal getting, without altogether stopping work in the mine, but generally it is advisable, especially if the nystagmus be of a high degree and of some standing, to recommend cessation altogether from work underground. After relief has been effected, return to the mine is practicable, provided the head can be kept straight and the upward turn of the eyes avoided. Resumption of the old kind of work is followed, sooner or later, by a recurrence of the symptoms. Medicinal treatment is also of service.

Finally, as regards the occurrence of nystagmus in other occupations than mining, Snell[b] states that he observed the affliction, among others, in "compositors, metal roller, plate layer, plank cutter, saw maker, sanitary tube maker, fitter, iron founder, cage worker in a mine, glass manufacturer, youth in confectionery warehouse, and a man engaged in hanging up harness, and in another employed at the screens at the surface of a coal mine."

All of these instances, Snell points out, occurred under circumstances comparable to mine work, particularly as regards the strain upon the elevator muscles of the eyeball, on which, in his opinion, the degree of illumination had no effect. This conclusion, however, is not generally accepted.

FREQUENCY OF OCCURRENCE.

The first practical question is the probable number of miners affected with nystagmus. There are, unfortunately, no conclusive data on this subject, and the results of the only investigation that appears to have been made in this country—that is, in the State of Illinois—proved negative. According to the census of 1910 the number of men employed in coal mines in the United States was 613,519. If the proportion of miners affected with nystagmus were 5 per cent, the number of such cases in this country would be 30,676. In view of the paucity of references to nystagmus in American medical literature, it is extremely doubtful whether this proportion holds good for this country, as, seemingly, there have been few cases in American mines, although no thoroughly qualified opthalmic study has yet been made.

One of the most important contributions including American data was published some years ago by Nieden,[c] of Bochum, the center of the coal-mining district of Rhenish Prussia. The study includes an examination of 7,500 miners. The pure rotatory form of nystagmus was found to occur in 72 per cent of the cases, the oscillating form in 12.5 per cent, and the mixed form in 15.5 per cent. Nieden questions the accuracy of Romiée's conclusion regarding a proportion of 20 per cent of nystagmus cases; and his own investigations made for the purpose of determining the facts, at least for the mining districts of Rhenish Prussia, were made with characteristic German thoroughness, and the existence of nystagmus in an acquired form was accurately determined in 299 cases out of a total of 7,416 miners, or 4.03 per cent.

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[a] Snell, Simeon, Eye diseases and eye accidents in relation to industrial compensation, in "Dangerous Trades," by Thomas Oliver, London, 1902, pp. 760–762.

[b] Snell, Simeon, Loc. cit.

[c] Nieden, A., Der Nystagmus der Bergleute, Wiesbaden, 1894, 140 pp.

On examination of 2,003 miners returning from work he found a proportion of 3.2 per cent suffering from nystagmus, whereas 1,913 men on commencing work were found to suffer in the proportion of 2.9 per cent. This result applies to a particular section and is, therefore, not strictly comparable with the total for the entire group examined, for which the combined percentage of nystagmus cases was 4.03. The difference as regards the occurrence of nystagmus on entry or exit can not be considered of great importance, but a more extended inquiry might disclose a more pronounced deviation from the normal.

Nieden adds an extremely interesting comparison of the frequency of nystagmus, based on his own examinations of miners and the results of his own private practice. Out of 3,017 miners requiring attention on account of eye troubles during a period of seven years, there were 172 cases of nystagmus, or 5.6 per cent. Against this proportion Nieden quotes 29,640 private cases of eye afflictions, out of which only 0.54 per cent were cases of nystagmus. In his opinion, therefore, the high proportion of 20 per cent as given by Romiée was not sustained by the experience in the Bochum mining district.

It is quite possible, however, that wide variations would be found to exist in different coal fields, for it is safe to maintain that the disease in the coal areas of the United States is relatively rare; in fact, Nieden points out that, according to his own investigations, most of the cases of nystagmus occurred among miners working in narrow seams, and that miners in some sections, where mining conditions were better, were practically free from the disease. Thus, for illustration, he determined that in the coal seams north of Bochum 7 per cent of the miners were afflicted with nystagmus, whereas in the coal seams south of Bochum only 0.25 per cent were affected. Upon further inquiry, however, he ascertained that in the northern coal seams the use of safety lamps was practically universal, whereas in the southern coal seams most of the men worked with open lamps and therefore under better conditions as regards illumination. He determined, by means of strictly scientific methods, that a miner using a Davy safety lamp during an eight-hour period worked under about one-third the amount of illumination normally provided by an open lamp.

On examining the records, he found that of 117 miners treated by him on account of nystagmus, 107, or 91.4 per cent, used safety lamps, whereas in two mines using open lamps and employing 772 men, only 0.35 per cent was found to be afflicted with nystagmus. He points out, however, that it was not only the insufficient illumination derived from the Davy lamp, but also its imperfect construction as regards the largest amount of possible effective illumination that was to be held responsible as a causative factor in nystagmus.

The relative frequency of this disease is referred to by Shufflebotham as follows:[a]

> Dr. Court has stated, as a result of the examination of several thousands of workmen, that 35 per cent of coal getters are subject to this disease to some extent. Snell estimated that 5 per cent of all colliery workers were affected, but he did not discriminate between different kinds of work in the coal pit. Nieden, who examined nearly 30,000 coal miners, agrees with Snell that the frequency of nystagmus in underground workers is somewhere about 5 per cent. In the north of France Dransart and Famechon have given 10 per cent as the number affected. Romiée and Thiebert, of Liege, during 1908 and 1910 examined 5,000 workmen in 27 collieries. More than three-fifths were coal getters, and on the average 21 per cent were affected with symptoms of nystagmus; in collieries lighted by lamps burning heavy oils 37 per cent of the coal getters were affected. Romiée had made a similar inquiry in the same district in the years 1877–78, and the result of his later inquiry was to show a marked diminution in the number of cases as well as in the severity of the symptoms. Stassen, who in 1909 examined 3,385 colliers descending into the pit, and also on their return to the surface, found that 15 per cent of the workers were affected before commencing their work and 22 per cent at the end of the shift.
>
> Roger, of Hondeng-Geognies, as a result of examining over 7,000 workmen, came to the conclusion that 17.5 per cent were suffering from nystagmus. Liebert, the chief inspector of mines to the Belgian Government, found different percentages of miners affected in different districts. In one series of examinations which he conducted with the help of Romiée and Thiebert he found that of 305 workmen examined in one pit 73 were affected with miners' nystagmus, giving a percentage of 23.9, and he refers to a memoir dealing with 3,685 workmen, among whom 704 showed symptoms of this disease, or a percentage of 19.1.

OTHER EYE DISEASES OF MINERS.

Aside, however, from the question of imperfect or insufficient illumination, Nieden[b] found that in a preponderating number of cases the miners suffered from other eye afflictions, including trachoma, dimness of the cornea, chronic iritis, irido-choroiditis, atrophy of the optic nerve, etc., all of which, of course, would predispose to nystagmus under the special conditions of underground work at the face of the seam. The only specific suggestion that he makes as regards prevention is the necessity for better artificial illumination by means of safety lamps, and he refers to electric mine lamps used in the Newcastle (England) district, but these, of course, do not indicate the presence of dangerous gases.

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[a] Shufflebotham, Frank, The hygienic aspect of the coal-mining industry in the United Kingdom: Brit. Med. Jour., Mar. 21, 1914, p. 648.

[b] Nieden, A., Der Nystagmus der Bergleute, Wiesbaden, 1894.

CONCLUSIONS OF LINDEMANN.

On the occasion of the Fifteenth International Congress on Hygiene and Demography, Lindemann,[a] chief medical director of the Bochum Miners' Union, contributed an address on the occupational diseases of miners, in which the subject of nystagmus is briefly referred to. He admits that the disease is of comparatively common occurrence, and points out that general debility, anemia, and alcoholism may be contributory causes, aside from the high underground temperature and excessive muscular strain. He dissents from certain conclusions by Snell with regard to the inability of miners suffering from nystagmus to recognize in time the blue cap on the safety lamp, indicating dangerous gaseous conditions. According to his own investigations, miners suffering from nystagmus were, without exception, able to determine the presence of fire damp to the extent of 2 to 3 per cent with absolute certainty. He refers to the rule of the Allgemeiner Knappschafts Verein zu Bochum (Bochum Miners' Union) (which is the compulsory miners' insurance association) that miners afflicted with nystagmus are not permitted to work underground, and that nystagmus itself entitles to compensation, both as regards money payments for support and medical treatment, as well as an invalidity pension. He states that an additional rule is to the effect that miners whose normal vision has been reduced 50 per cent are not permitted to work underground. As regards treatment, he states that good results follow only when underground work is discontinued at an early stage of the disease.

In this connection a brief reference may be made to the recently published experience of the Bochum Miners' Union[b] for the year 1912, as regards the frequency of nystagmus as a cause of invalidity. Out of 3,605 cases of invalidity, 649, or 18 per cent, were on account of nystagmus, and 75, or 2.1 per cent, on account of other diseases of the eye. As the membership of the fund for the year 1912 was 376,000, this would be equivalent to an invalidity rate on account of nystagmus of 1.73 per 1,000 employed.

The foregoing preliminary observations emphasize the practical importance of nystagmus wherever the disease prevails to a considerable extent. A strictly localized investigation should limit itself to a mining district in which the miners use safety lamps and undercut the coal with the pick.

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[a] Lindemann, Wilhelm, Über die Unglücksfälle und Berufskrankheiten der Minen und Tunnelarbeiter: Trans. Fifteenth Int. Cong. on Hygiene and Demography, vol. 3, 1913, pp. 673–690.

[b] Verwaltungs-Berichte, Allgemeiner Knappschafts Verein zu Bochum, 1912, Bochum, Germany, 1913.

NYSTAGMUS AS A MINING PROBLEM.

Nystagmus is not referred to in the "Report on Mining Methods and Appliances Used in the Anthracite Coal Fields,"[a] published by the Second Geological Survey of Pennsylvania in 1883. There is also no reference to the disease in the section on "Hygiene of Occupation"[b] published in Buck's "Hygiene and Public Health," in 1879. The importance of the disease has come to the front as a practical question in mine management only since the adoption of the workmen's compensation act in England of 1906 and the inclusion of nystagmus in the schedule of occupational diseases for which compensation is required to be paid. In a treatise by Cockin[c] it is said under "Nystagmus" that—

> This is a disease which affects the nerves of the eyes; it is more prevalent among those who work by the light of safety lamps than among those who use naked lights. The cause of nystagmus is thought to be either the constant dazzling of the eyes by the bright concentrated light of safety lamps or the strain put upon the muscles of the eyes by work, such as holing. The symptoms of this disease are a twitching of the eyes and impaired sight.

This inadequate reference emphasizes the lack of appreciation of the importance of an affliction that may be much more common in this country than is generally supposed. As there is unquestionably close interrelation between nystagmus and the use of safety lamps, it is regrettable that the extended consideration given to this part of mine equipment in most of the textbooks on coal mining should be practically without useful references to the prevention of a disease which, wherever it occurs, is, without question, a most serious affliction of the men employed, and an important factor of cost in mine management wherever workmen's compensation laws require compensation to be paid for cases of nystagmus directly attributable to the employment.

MEDICAL CONSIDERATIONS.

It has therefore seemed advisable to enlarge upon the medical aspects of a problem that is practically certain, in the near future, to attract attention in the United States, if only along negative lines, to prove beyond a doubt that the affliction is not as common in this country as it is known to be abroad. As pointed out in an editorial in the Journal of the American Medical Association:[d]

> The careful study of occupational diseases is one of the features of the modern conservation movement coming with the recognition of the economic advantage which attaches to the preservation of health in the industrial population. As an instance of the financial aspects of some of these matters we may cite a recent estimate of the cost of the 1,618 cases of miners' nystagmus in the United Kingdom in 1910. The

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[a] By H. M. Chance; 573 pp.

[b] Buck, A. H., A treatise on hygiene and public health; Hygiene of occupation, by R. S. Tracy, vol. 2, 1879, pp. 1-96.

[c] Cockin, T. H., Practical coal mining, 1909, p. 405.

[d] Vol. 59, Aug. 17, 1912, p. 547.

compensation of these individuals is calculated at over $155,000, a figure which does not take into account the poor earning capacity of the men in the incipient stages of the disease and other profits lost by the employers. Aside from its purely humanitarian or scientific aspects, therefore, successful investigation of such an industrial disease promises to pay a rich return. This statement needs to be brought home to American captains of industry who have as yet made only a beginning in a direction almost certain to lead to a profitable outcome from every point of view.

Among miners nystagmus is an occupational neurosis characterized by an involuntary oscillation of the eye-bulbs on fixation. It seems to be confined to the workers in coal mines and prevents the miner from accurately fixing anything toward which his vision is directed. Such a disturbance of vision evidently must seriously impair the working capacity of an individual who needs to strike accurately with his pick or to match timbers well in collieries.

There are two prominent views with regard to the etiology of the disease. One of these attributes the nystagmus to the strain of accommodation in the presence of deficient light; the other view associates the disease with the positions taken by the colliers, and assumes that there is a local myopathy affecting the elevator muscles of the eye. The cause and prevention of miners' nystagmus has been investigated lately by Dr. T. L. Llewellyn. It is a striking fact that the disease does not occur in the metalliferous mines where safety lamps are not required. In mines where candles can be used or where electric lamps are in operation nystagmus is not found. Now the safety lamp gives much less light, quickly becomes dirty, throws shadows, and must be placed out of the reach of the picks. We are apt to overlook the amount of our light which is due to the diffuse reflection from the walls of the room in which we happen to be. In the coal mine practically all of the light is absorbed; hence the need of satisfactory sources of illumination.

The disease is shown to attack the men who use their eyes in a much larger proportion than the other men. A large proportion of them suffer from errors of refraction. All have weakness of accommodation. Llewellyn regards nystagmus as a disease of great complexity and one in which many factors are at work. The chief of these is strain caused by deficient light. He believes that, as the result of working for long periods in the comparative darkness of the pit, the cells of the retina probably lose their power of producing sufficient pigment for exact vision. This failure occurs sooner in fair blue-eyed people and in those who are subject to a greater eyestrain, owing to errors of refraction. The more frequent occurrence of nystagmus in winter, the loss of visual acuity, the dread of light, are all points in favor of this theory. Another is the oblique position in which the head is held in many cases, whereby an attempt is presumably made by the patient to bring a fresh part of the retina into action. Darkness itself, Llewellyn suggests, is not enough to set up nystagmus.

Here are the preventive measures proposed: No man with refractive errors should be allowed to work underground and no man should be employed without medical examination. Above all, however, comes the improvement in the lighting power of the miner's lamp. If possible a lamp giving a diffused light should be introduced. Improved ventilation also means a better light. The study of the introduction of electric lamps promises to be of great interest in this connection.

CONTROVERSIAL ASPECTS.

Much to the same effect is an extended editorial discussion on the subject in the British Medical Journal[a] of April 13, 1912. The editorial draws attention to the correspondence between Markham, a coal owner, and the Secretary of State for the Home Department, arising out of a letter to Markham from Dr. J. Court, of Stavely, Derbyshire, whose views are based on 40-years' experience in coal-mining. Court urged that an inquiry should be undertaken into the eyesight of all men and boys working in collieries and other mines in Great Britain, where both naked lights and safety lamps are used, in order to ascertain (1) the cause or causes of miner's nystagmus; (2) the duration and best means of cure; (3) whether there is a constitutional liability; (4) whether one attack predisposes to another; (5) whether mild cases of nystagmus incapacitate a miner for work underground; and if so, to what extent; and (6) whether miner's nystagmus causes the sufferer to be a danger to himself and other miners at work with him. An abstract from the editorial follows:

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[a] Pp. 853-854.

> There are two views as to the cause of miners' nystagmus. The one attributes it to eyestrain due to working in a badly lighted space with black light-absorbing surfaces; the other to strain of the extrinsic muscles of the eye, especially of the elevator muscles, due to the position of the miner when at work at the coal face, or when examining the roof of the workings to detect gas or threatening falls. The view hitherto most generally accepted is the second, a theory which brings the condition into the same category as writer's cramp and other occupational neuroses. This theory was strongly held by the late Mr. Simeon Snell, who supported it by many cogent arguments drawn from his long experience in treating eye affections among coal miners. He had the support of Nieden, Dransard, and some other continental authorities, but the theory has always been open to the objection that the disorder is seldom met with except among men working in coal mines; those engaged in other mines, it is said, are seldom or never affected in this way. In a paper on the causes and prevention of miner's nystagmus, communicated recently to the Royal Society by Dr. J. S. Haldane, Dr. T. L. Llewellyn, of Bargoed, Glamorganshire, advanced the theory that the nystagmus was due to a condition of imperfect centripetal impulses (imperfect fixation, disturbance of equilibrium, etc.), the intimate connection between the centers governing the associated movements of the eyes being lost and incoordinate movements ensuing. Dr. Haldane has informed the Home Secretary that Dr. Llewellyn's researches in a number of coal fields and also among metalliferous miners confirm Dr. Court's conclusion as to the connection between nystagmus and the very poor light given by ordinary safety lamps. Dr. Llewellyn found errors of refraction (hypermetropia, or astigmatism) present in 93 per cent of 280 cases examined, and concludes that the personal proclivity to the disorder which is undoubtedly an important factor, since only a small percentage of coal miners are affected, may be due to these defects, but he admitted that accident, shock, and ill health are also predisposing factors. He found that the disorder certainly diminished with improved illumination, being almost unknown in naked-light districts, and the principal preventive measures he indicated were improvement of illumination (which Dr. Court also advocates, suggesting the use of electric lamps), employment of coal-cutting machines in thin seams, and the elimination of unfit workers by medical examination.

NYSTAGMUS A MINE-SAFETY PROBLEM.

The practical importance of these observations is obvious. The evidence upon several important controversial points, however, could hardly be considered sufficient. Snell,[a] in his address as president of the British Medical Association in 1908, described experiments made with the assistance of Dr. A. Stokes, a Government inspector of mines, "which seem to establish the very important practical point that an underground coal worker suffering from miner's nystagmus was not able to recognize the 'cap' which forms on a safety lamp in the presence of fire damp." As, under given conditions, it is desirable to recognize a quantity of gas smaller even than 2 per cent, the implication was that miners suffering from nystagmus in dangerous mines requiring the constant use of safety lamps should not properly be intrusted with their respective duties. According to the editorial in the British Medical Journal,[a] —

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[a] Snell, Simeon, President's address delivered at the seventy-sixth annual meeting of the British Medical Association: Brit. Med. Jour., Aug. 1, 1908, p. 243.

> The disability to see the "cap" is due to the fact that the oscillations of the eyeballs give the sufferer the impression that the object looked at is in motion; he sees his safety lamp and its flame as if moving, or "dancing," as he expresses it. The more rapid the oscillations the more rapid the apparent movement of the lamp, as the oscillations may vary from 100 to anything up to, say, 350 in a minute, the apparent movements of the safety lamp may be very quick indeed, producing little more than the appearance of a blur of light. The oscillations may be to-and-fro, or rotary, or the two may be combined, but rotary movements are seldom, if ever, absent, and a miner frequently describes the safety lamp as appearing to move rather more in an eclipse than in a circle. The nystagmus is arrested by turning the eyes downward, but in searching for fire damp the examiner must give particular attention to the roof, and consequently must often look up when lying or stooping in a very constrained attitude.

The foregoing discussion was evidently intended to emphasize the necessity for medical examination, particularly with reference to the claims for compensation made on account of nystagmus in recent years in the United Kingdom. According to Llewellyn,[b] 1,618 men suffering from miners' nystagmus received compensation in the United Kingdom in 1911. The subject was therefore shown to be one of fairly considerable importance to the mining industry. Even more important was the final conclusion, that "were it established that nystagmus in the 'deputies' or 'firemen' [equivalent to fire bosses in the United States] whose duty it is to search for fire damp was even an occasional cause of explosions, the arguments in favor of systematic medical inspection would be greatly strengthened."

FACTORS OF CAUSATION OF NYSTAGMUS.

The conclusions of Snell were not new to those familiar with the subject. As far back as 1891, the Medical Record[c] of New York contained a statement to the effect that—

> Dr. Snell persists in his opinion that there is no reason for supposing that nystagmus or the nervous disease which manifests itself in a morbid winking of the eye, so common among miners, is attributable to working by the imperfect light of the safety

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[a] Apr. 13, 1912, p. 853.

[b] Llewellyn, T. L., A lecture on miners' nystagmus. Delivered at the Mining Machinery Exhibition, London, on May 31, 1913: Brit. Med. Jour., June 28, 1913, p. 1359.

[c] Anonymous, Morbid winking by miners: Medical Record, Oct. 10, 1891, p. 468.

lamp. The fact that the complaint is found among the workers with naked lights is in itself sufficient to throw doubt upon the long-prevalent theory. The Government inspector of mines for the Midland District notes, on Dr. Stoke's authority, the case of a man who, after working with the Davy lamp for 14 years without injury, proceeded to work at a pit where candles were used. He had been employed there for some three and one-half years, and during the last 12 months he experienced symptoms of nystagmus, and had ultimately to leave work and seek medical aid. Dr. Snell has collected a mass of facts and a record of a large number of instances of men suffering from the infection, which will, he believes, be very corroborative of the views he has before set forth, namely, that the prime cause of the affection is to be found in the position assumed by the miner at his work.

OPHTHALMOLOGICAL TESTS.

In 1908 the Engineering and Mining Journal[a] contained an article on the subject, bearing also on the investigations of Dr. Snell, briefly summarized below:

> A miner with nystagmus when looking at a safety lamp gets the impression that the object looked at is in motion. This is caused by the oscillations of the eyeball, and is due to the weariness of the elevators of the eyes caused by working in constrained positions in the mine.
>
> Forty-eight miners were tested in the ophthalmoscopic dark room in the Sheffield hospital. These men were brought from 13 different collieries and were examined with regard to their capacity to detect the "caps" of safety-lamp flames. All of these men failed to detect a "cap" until a dangerous amount of gas was present. One could not see a large "cap" at all. He said his lamp was "spinning too much"; another could not see a "cap" until he steadied his eyes. He then saw a 1-inch "cap." One who had nystagmus in a marked degree reeled like an intoxicated man when rising from the floor from the kneeling position he had assumed in reading the lamp. The lamp was full of gas before he detected a "cap."
>
> The results of the experiments were so astonishing that members of the association now advocate the periodical medical examination of all officials whose duty it is to make the daily gas tests in coal mines. Each inspector should be tested for vision as carefully as locomotive drivers and signalmen. Gas tests with the safety lamp are almost useless unless the testor has good vision. It might be valuable if the question of vision would be investigated by the Accident in Mines Commission, now sitting in Pennsylvania.

The suggestion that the subject should be investigated by the Accident in Mines Commission of the State of Pennsylvania was not carried into effect.

The technical aspects of astigmatism and visual acuity are extremely involved and do not permit of an extended discussion on this occasion. The following extract, however, from an address on miners' nystagmus by Shufflebotham[b] is included as suggestive of the direction in which inquiries of this kind are most likely to be practically useful:

> Visual acuity is nearly always diminished, even in convalescent cases where there is no oscillation of the eyeballs. In severe types of nystagmus where the oscillatory

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[a] Eng. and Min. Jour., Mar. 21, vol. 85, 1908, p. 1012.

[b] Shufflebotham, Frank, Miners' nystagmus: Brit. Med. Jour., Mar. 21, 1914, p. 650.

movements of the eyeballs are constant, it is impossible to estimate the field of vision. Out of between 60 and 70 cases of coal miners' nystagmus Cridland found it possible to take the field of vision in 25. Nearly all the patients he investigated were men who had been compelled to give up their work on account of the severity of the symptoms. The results of his examination of these cases showed—

1. That contraction existed for white, blue, and red in practically all the cases examined.
2. The contraction was of concentric type and symmetrical in shape, although not always in depth.
3. In the majority of cases the colors were in their correct order, but occasionally interlacing of the red and blue occurred, the correct order being recovered as the case improved.
4. The contractions for red and blue were generally greater than those for white and rather greater for red than blue.
5. By grouping the cases into mild, moderate, and severe types the fields broadly showed corresponding contractions.
6. Speaking generally, as the disease improved the fields of vision improved, but contraction persisted as long as any subjective symptoms were present and although oscillatory movements could not be elicited by any test.
7. Most of the cases showed more or less marked signs of such symptoms as clonic spasm of the eyelid, twitching of the neck, etc., but there seems to be no direct relationship between the presence and the degree of these signs.

AMERICAN INVESTIGATIONS.

The question, however, was taken up by the Illinois Commission on Occupational Diseases, which made its report [a] under date of January, 1911.

The following is our report of our investigation of miners' nystagmus in the State of Illinois. Two factors are operating to make this disease less frequent. Firstly, the condition is limited to pick miners, and they are becoming less numerous yearly on account of the increase of machine mining. The following figures, taken from the Illinois Coal Reports for the year ended June 30, 1908, show the percentage of machine mining: Total quantity of coal mined by hand, 34,062,029 tons; total quantity of coal mined by machine, 15,210,425 tons, or over 30 per cent; total number of men employed about the mine in all capacities, 70,841; total number of men employed in actual mining, 46,194; total number of men employed in machine mining, about 16,000; total number of pick men, 30,194. From the foregoing we see that of the total of 70,841 employed only about 30,194 [or 42.6 per cent] belong to the class of workmen subject to miners' nystagmus.

Secondly: The disease is confined to those pick men who work with the eyes in an unnatural position; that is, looking upward and to one side. Previous to the passing of the gross-weight law some years ago, the men were paid only for coal which would pass over a screen of a certain size. This caused the men to do a lot of overhead pick work in order to obtain the coal in large pieces. The gross-weight law forced the owners to pay for the entire quantity mined, and the miners now assume a more natural position. Of the 30,194 pick men in Illinois, we examined the eyes of about 500, or one-sixtieth of the entire number, without finding a single case. Two men had complained of subjective symptoms of the disease in the past, but at the time of the examination showed no objective symptoms.

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[a] Lane, Francis, and Ellis, J. B., Report of Commission on Occupational Diseases; Miner's nystagmus, 1911, p 155.

Conclusions.—The disease is rare, and, owing to the passage of the gross-weight law and the increase of machine mining, it is becoming less frequent in the State of Illinois. The only cure is cessation of the occupation which caused it.

The conclusions of this investigation were negative, but the investigation was seemingly not made with the required degree of scientific thoroughness.

FREQUENCY OF NYSTAGMUS IN ENGLAND.

A further original investigation was made by Butler,[a] honorary ophthalmic surgeon to the Coventry and Warwickshire Hospital. Butler points out that—

In all colliery centers miners' nystagmus is a common disease. It is scheduled under the act of 1906 as a condition for which a miner may claim compensation, and so a knowledge of its leading characteristics is essential to all medical men practicing in such a district. The average ophthalmic textbook devotes only a few lines to the affection, and even the meager information given is apt to be somewhat dogmatic and inaccurate.

Butler further states that the symptoms in a severe case are characteristic, and briefly describes them as follows:

The eyes oscillate violently, the eyelids twitch, and the man appears to be, and often is, in a state of great nervous agitation. When his visual acuity is tested with the types it will generally be found to be as low as one-tenth of the normal. He is quite unable to read or to continue at his work, and will frequently complain that he can not see his way about in the dark. But such a violent attack is uncommon, and it will be, therefore, proper to consider in detail the more useful manifestations of the affection.

The history is typical. The miner has almost invariably worked some years in the pit, and has in most cases been a "holer," one who lies on his side and undercuts the seam of coal. He first notices that at the end of a day's work the lights begin to "dance." They may dance vertically, horizontally, or in a circular fashion like a Catherine wheel. He can for a time overcome this oscillation by looking down and resting his eyes. Soon, however, the dancing commences earlier in the day, and he more frequently has to "steady" his eyes, and finally the lights begin to dance as soon as he enters the mine, and work becomes impossible. At this period the subjective sense of movement may cause vertigo.

In the early stages of miners' nystagmus the sufferer is free from trouble when he leaves the pit, but as the disease progresses nystagmus is present when it grows dark and the street lamps are lighted. Eventually nystagmus is always noticed, even in daylight.

At the beginning of the case nystagmus commences only when the eyes are considerably raised, then it appears as soon as the gaze rises above the normal plane, and later it ceases only when the subject looks down. In fact, the severity of the attack can be accurately gaged by the angle above or below the primary position at which nystagmus can be elicited. The position of the head, however, has nothing whatever to do with the matter; nystagmus can be demonstrated just as easily in the supine posture if the eyes be directed toward the brows as it can in the erect. Peters is quite incorrect when he states that nystagmus ceases if the head be thrown back. It does so in many cases if the patient looks at the same object, but if he moves his eyes back *pari passu* with his head nystagmus does not cease.

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[a] Butler, T. H., Miners' nystagmus: Brit. Med. Jour., Mar. 5, 1910, pp. 558-559.

In a slight case, or one which is in process of cure, it may often be impossible to detect any nystagmus by simply raising the eyes. Reid has taught us that if we rotate the patient several times, until he is a little giddy, and then direct his eyes to the ceiling, nystagmus may appear. If we can produce no nystagmus by this method it is safe to assume either that the case is not one of nystagmus or that it has been cured.

The direction of the nystagmus may be vertical, horizontal, or circular. In my own practice the vertical variety has been rare. One eye may have a different kind of nystagmus from the other.

Hemeralopia may be present. Court found it in 127 cases out of 164; Dransart detected it in 5 per cent of his patients. Romiée states that he has never seen this symptom, although he has examined several thousand individuals. My own experience has been that night blindness is undoubtedly a symptom of the disease. Probably at least 25 per cent of all cases are unable to see in the dusk.

Visual acuity is unaffected when the eyes are at rest. If the types be placed on the floor level and the miner stand upon a chair, he may read the last line; if he sit down and the types be hung on the wall, he may fail to read the top line.

The "holing" mentioned by Butler is somewhat at variance with American mining practice and has been described as follows in an address on miners' nystagmus by Frank Shufflebotham:[a]

Symptoms of nystagmus are most commonly found among miners engaged in holing, a process which consists of cutting the coal seam so as to get out the coal in pieces as large as possible. The holer lies on his side with his knees drawn up and his head thrown backward, and he strikes the coal with a horizontal swing, the lamp being placed near his feet. He may undercut the seam or "top cut" it, but in either case the muscles of the eyeballs are continually in a strained position, generally in an upward or oblique direction. As a result of this eyestrain the elevator muscles suffer from strain and cramp. Similar effects are found in other muscles, producing wry neck, twitching eyelids, and tremors of the head. Holers as a class are undoubtedly more predisposed to nystagmus from the nature of their constrained work; hewers and the loaders who are working at the face come next in the liability to the onset of the disease.

TYPICAL CASES.

The symptoms and personal history of the disease have been quoted in full on account of their unusual practical value. Nystagmus unquestionably is often mistaken, at least in its initial stages, for ordinary eye afflictions; for, as observed by Butler,[b] the average ophthalmic textbook devotes only a few lines to the affection, and much of the information is dogmatic and inaccurate. It has therefore seemed proper to add the following description of a typical case, presented by Butler[c] at a meeting of the Coventry division of the British Medical Association in 1910.

T. R., aged 45, was a miner in the Newdigate colliery, a lamp mine; had been a miner all his life.

About six months ago he began to notice that the lamps were dancing up and down. He had to sit down and "steady" his eyes. Three months ago, when he was examining the roof, a piece of coal fell upon his nose and cut his face. Had he not had violent nystagmus he would have seen that a large fragment was loose and would have avoided it. After the accident the nystagmus got much worse. He sees very badly at night, not only because everything is in motion, but because there is a "sort of mist before his eyes." He sees a little better if he looks down, but not so well as his mates do. In fact, he has slight hemeralopia.

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[a] Shufflebotham, Frank, Miners' nystagmus: Brit. Med. Jour., Mar. 21, 1914, pp. 348-349.
[b] Butler, T. H., Miners' nystagmus: Brit. Med. Jour., Mar. 5, 1910, p. 558.
[c] Butler, T. H., Op. cit., pp. 558-559.

Condition when first seen: Violent nystagmus and twitching of lids. Vision=6/60. Advised to give up his work underground entirely and permanently.

Condition a month later: The eyes were normally at rest, but if he looked at an object fixedly for a few seconds his eyelids began to blink and twitch violently and he looked away as though shielding his eyes from a dazzling electric arc. As soon as he looked upward violent twitching and vertical nystagmus commenced.

$$\text{R. V.}=6/60\text{c}\,\frac{-3.5}{-2,\ \text{axis horizontal}}=6/9.$$

$$\text{L. V.}=6/60\text{c}\,\frac{-3}{-1,\ \text{axis horizontal}}=6/9$$

The fundus was normal, but could be seen only with great difficulty on account of the twitching of the lids. He was unable to read even when he looked down.

The patient subsequently improved considerably, but he can not do any work, for as soon as he looks fixedly at an object the oscillations commence.

OCCUPATIONAL PREDISPOSITION.

Butler [a] properly observes that this is a most instructive case. In the first place, he points out, it shows the classical symptoms, which have been ameliorated but not cured by rest. Before the compensation act this miner would have been discharged and left to take charge of himself as best he could; under the act of 1906, however, the coal-mining corporation was responsible for the disease and had to provide for his needs. In this case also nystagmus conduced to an accident and the accident aggravated the disease. As regards the etiology of nystagmus, or the causative factors responsible for the occurrence of this affliction, Butler [b] states that—

> The textbooks say that it is strictly comparable to scrivener's palsy, due to cramp of the elevator muscles of the eye. This is the theory enunciated by Snell, by Nieden, and by Dransart; it was for long accepted without criticism or challenge, and has been copied from book to book, rather as a proved fact than a hypothesis. To be brief, the view that the miner is always straining his eyes upward, producing muscle fatigue, which results in nystagmus, does not account for the facts. First, the miner does not strain his eyes upward; like other sensible mortals, he makes himself comfortable and moves his head, not his eyes; secondly, there is no proof that any muscle fatigue exists, and conclusive proof that it does not; and, finally, if muscle fatigue did exist, it would produce a tetanic and not a clonic spasm. Nystagmus is essentially a disease of the collier; it is not found in metal mines, where men work under similar conditions to those obtaining in coal mines, but with one great difference—the metal mine is not bounded by glittering black walls.

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[a] Butler, T. H., Miners' nystagmus: Brit. Med. Jour., Mar. 5, 1910, p. 559.

[b] Butler, T. H., loc. cit.

SAFETY LAMPS AS A CAUSE OF NYSTAGMUS.

In this connection Butler[a] makes the interesting observation that the disease was first described at the time when the Davy lamp was introduced, and that as soon as the use of safety lamps was enforced by law it became frequent. In his own words, as soon as the illumination of the miner's candle, which gives 0.5 candlepower, was replaced by that of the Davy lamp, with its feeble glimmer of 0.28 candlepower, cases of nystagmus became increasingly frequent. The miner's lamp has been improved now and the disease is much less common than it was. The ordinary lamp used in England in 1910 when clean has a candlepower of 0.44, but as it gets covered with dust and the wick chars its light falls off rapidly.[a]

The method of amelioration is, therefore, suggested by this remark, in that it should not be difficult to insist, if necessary by law, upon the keeping of the safety lamps not only locked but also clean, so as to provide the best possible illumination.

MINE DARKNESS AS A CAUSE.

In concluding his interesting and valuable contribution to the subject of nystagmus, Butler[a] refers to the claim that darkness is primarily a cause of nystagmus. This, he insists, can not be so, as employees in photographic studios, who work for hours in absolute darkness, do not contract nystagmus, nor do boiler makers and other artisans who work by feeble light. He therefore holds that the only theory that can explain the disease is that suggested by Reid, of Nottingham, and Nuel, of Belgium, that it is a disordered cerebration, or, in other words, a defect in the brain and not of the eye muscles. It is produced, according to this view, by the peculiar work of the miner, the long-continued rhythmic movements of the pick in comparative darkness. Finally, the argument is advanced that the attempt on the part of Snell to show that compositors and other workmen occasionally acquire occupational nystagmus will not stand the test of a critical examination, which would lead to the conclusion that these men did not suffer from true miners' nystagmus, but that the disease always was, and still continues to be, the special disease of the colliery.

ERRORS OF REFRACTION AS A CAUSE.

This address led to considerable correspondence, which brought out some additional phases not fully discussed by Butler and some controversial views of considerable practical importance. A letter by Carruthers,[a] assistant medical officer of health of the county of Derby, follows:

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[a] Butler, T. H., Miners' nystagmus: Brit. Med. Jour., Mar. 5, 1910, p. 559.

> SIR: I notice that, when discussing the etiology of miners' nystagmus (Mar. 5, p. 558), Dr. Harrison Butler did not suggest an error of refraction as a possible predisposing cause, although the case which he describes shows this. I mention this because I know that as a body miners systematically neglect their eyesight, this fact having been forcibly brought home to me during the last few months whilst examining school children in a mining district, the parents simply stating that if their child had to wear glasses he would not be allowed in the pit. I understand that at present no examination of the eyes is required by the owner before a man is employed as a collier; and surely, if evidence could be produced to show that a definite relationship exists between errors of refraction and miners' nystagmus, the owners for their own protection would soon insist on such an examination.
>
> Dr. Harrison Butler states that there is no muscle fatigue (of the eye) when the man is at work; but during such heavy work, when practically all the man's muscles are in use, how can those of the eye escape the general fatigue of the body? If, in addition, a serious error of refraction exists, which of itself would lead to strain, this would be especially noticeable at the end of the day's work, the time when the nystagmus first appears; and I suggest that the nystagmus is akin to the physiological tremor of the hands which many people have after great physical exertion, but that, of course, it quickly becomes pathological as the conditions develop.
>
> It may be asked why, if these arguments are correct, miners' nystagmus does not occur as soon as the man becomes a collier? But then his tissues are young, and can overcome the strain imposed upon them, and it is as he gets older and is still subjected to the same conditions of very heavy work in a poor light and in a bad position that the strain is felt and nystagmus shows itself.

Ashforth[b] later contributed a brief statement which is also given in full:

> SIR: The only excuse I can offer for entering on this subject is that I live in a colliery district. Whether the fact that Dr. Harrison Butler did not mention errors of refraction as a cause directly was simply an error of omission, or whether he considered it a contributing cause, but thought it unnecessary to state, I think, matters very little. As in other discussions, one is very apt to believe greatly in himself and his own limited experience, for limited it is.
>
> Dr. Carruthers, so far as I can judge, has simply concluded that miners neglect their eyesight because a few parents have said something about their children and the pit. Now that would lead one to think nystagmus was a modern disease or ailment; but I am certain Dr. Carruthers will agree it is not. As it is, some people avoid glasses because of the compensation act. Again, this act is new (comparatively), and can not account for nystagmus before the act, because miners would have no fear about wearing glasses or having their eyes examined. I agree with Dr. Harrison Butler that there is no muscle fatigue of the eye, and disagree with Dr. Carruthers when he suggests that all the man's muscles are in use. I agree that a serious error of refraction may contribute, but I do not believe it to be the cause; personal experience in colliery districts has not taught me so. It is not safe to compare or draw an analogy between nystagmus and a physiological tremor of the hands.
>
> As to the tissues being young and able to resist, I may state that all the cases I have seen have been men under 40; some I have seen over 50, but they are not so numerous.
>
> In conclusion, might I suggest that the cause might as easily be found in the retina as anywhere else?

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[a] Carruthers, W. D., Miners' nystagmus: Brit. Med. Jour., Mar. 12, 1910, pp. 666-667.

[b] Ashforth, T. L., Miners' nystagmus: Brit. Med. Jour., Apr. 9, 1910, pp. 901-902.

In reply to these two letters, Butler [a] made answer as follows:

> SIR: I unfortunately did not notice Dr. Carruthers's letter in the Journal of March 12 at the time. It would appear likely that an error of refraction would be a predisposing cause, whether one regarded the disease as a fatigue cramp or as a loss of coordination due to partial loss of fixation. But supposition and theory must bow to fact, and the fact is that errors of refraction are found among nystagmic miners in exactly the same proportion as among the rest of the population. Some of the worst cases I have seen have been emmetropic, and have shown no error of muscle balance, so we can only conclude that errors of refraction have nothing to do with the matter. This is not the place to discuss with Dr. Carruthers the etiology of the disease. He will find the whole question argued out in my paper on the subject in The Ophthalmoscope, to which I alluded in my article published on March 5. At the end of this paper there is a full bibliography dealing with the subject. I would recommend him to read Dr. Reid's paper in Brain, and then to examine a long series of cases for evidence of muscle strain. The case published in the Journal of April 16 is almost positive proof that cramp of the elevators has nothing to do with the production of the disease. In this highly interesting case nystagmus appeared only when the miner looked down.

These letters bring out the imperfect status of the whole question as regards the essential points of material importance, not only to the physician and the miner, but also to the mine manager and the courts called upon to pass judgment in the arbitration of cases of workmen's compensation.

FATIGUE OF VISION AS A CAUSE.

The British Medical Journal also reports an animated discussion regarding nystagmus, between Romiée and Thiebert, both of Liége, and Moret, of Charleroi, Belgium.[b] The two former concluded that miners' nystagmus was due to insufficient lighting, was benign in nature, and rarely interfered with ability to work. They strongly objected to the theory that nystagmus involved an increased liability to accident. Moret discussed the causation, concluding that the infection was a neurosis produced by ocular fatigue due to darkness, combined with fatigue of the muscles, notably the elevators, from the strain of looking in an abnormal direction. A number of French representatives insisted on the risk of accident from this condition, and Shufflebotham[c] pointed out that nothing had been said respecting the subjective and objective symptoms that occurred apart from the ocular symptoms.

The foregoing discussion aroused considerable interest and resulted in several important papers by qualified authorities familiar with the actual facts of the existing situation in the United Kingdom. Elworthy,[d] inspector of injured workmen to the Ebbw Vale Co., read a paper on miners' nystagmus before the Monmouthshire Division of the British Medical Association. After first pointing out that miners' nystagmus is a disease peculiar to coal miners, and that on the basis of personal inquiries, no cases had been found to occur in the Cornish tin mines nor in the lead mines of the Isle of Man, Elworthy replies to the question as to why it is that nystagmus occurs only in coal mines, to the effect that it is the entire absence of color that makes all the difference in the underlying conditions responsible for its frequency among colliers. He [a] remarks that—

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[a] Butler, T. H., Miners' nystagmus: Brit. Med. Jour., Apr. 23, 1910, p. 1024.

[b] Report of International Congress on Diseases of Occupation: Brit. Med. Jour., Oct. 1, 1910, p. 980.

[c] Shufflebotham, F., Miners' nystagmus: Brit. Med. Jour., Oct. 1, 1910, p. 980.

[d] Elworthy, H. S., Miners' nystagmus: Brit. Med. Jour., Nov. 19, 1910, pp. 1577-1580.

> I take it that the cause is fatigue of the eye, resulting from working by artificial light with a black background and nearly black surroundings. There is the blackish "rubbish" or "slack" above and below the coal, and the jet black coal with some sparkling facets which reflect the light. The monotony is not relieved by other colors. The miner may come to work with clean face and clothes, but in a few hours all is more or less black from the dust. Then he has to fix with his eye the point at which to strike with his mandril or to lift out lumps of coal against a black background. When he turns his eyes away from the coal there is no color relief. To make matters worse, the majority of miners prefer to work in the day. The consequence is that for the greater part of the year it is dark when they get up and go to work; they work in the dark, and in winter it is dark soon after they come out. They therefore get the minimum of daylight, and the opportunity of seeing a variety of colors by daylight, which means physiological relief to the eye.

This is rather a novel point, not emphasized by the earlier authorities; but as another cause of fatigue to the eyes, he points out that when the miners have to walk a mile or more underground to reach the face where they work, "they proceed more or less in single file, each carrying a lamp which gives out light in every direction," with the result that "the miner walking behind another gets the glare of that lamp in his eyes all the time. * * * Then, after working his eight hours and his eyes being more or less exhausted, he has to make a similar journey back." On inquiry, Elworthy found that the men feel the effects of nystagmus most when returning from work with the intense glare of the lamp just in front of them, and many find it necessary to sit down and wait until the effect disappears.

OBLIQUE NYSTAGMUS.

As regards the theory that nystagmus was produced by working in a lying-down position, Elworthy was not in a position to give an opinion, as in the great majority of the mines of the Ebbw Vale district the colliers work in an upright position. He therefore had not seen a single case of oblique nystagmus. He,[b] however, points out that other underground workers, such as haulers, timbermen, and repairers in coal mines also acquire nystagmus, and that the only class that seems immune is hostlers, which he attributes to the fact that the underground stables, as a rule, are whitewashed. He therefore concludes that the only essential factor seems to be exhaustion of the eyes from working in the general blackness without any color relief.

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[a] Elworthy, H. S., Miners' nystagmus: Brit. Med. Jour., Nov. 19, 1910, p. 1577.

[b] Elworthy, H. S., Op. cit., pp. 1577-1580.

The discussion by Elworthy included the pathology, symptoms, and course of the disease, the varieties, diagnosis, prognosis, and the treatment of nystagmus in the light of practical experience, including the results of an analysis of 100 cases. All that he has to say is of unusual practical interest, except that with reference to pathology he limits himself to the statement that he is ignorant about the minute changes in the retina, or nerve centers of the orbital muscles. He says:[a]

> What seems to me to occur is, when a certain stage of exhaustion is arrived at, coordination is lost and spasm sets in; very much the same as in writer's cramp or other trade neuroses. Lastly, accommodation fails. The spasms are clonic, and may be regular or irregular, and confined to two opposing muscles or affecting more. In some cases the whole head is in a state of tremor. In the early or "latent" stage, although there are movements of the eyes, there is sufficient power of accommodation to prevent confusion of vision, but sooner or later this accommodation fails.

SYMPTOMS AND COURSE OF THE DISEASE.

As regards the symptoms and course of the disease, Elworthy[a] states that:

> Nystagmus seldom manifests itself until the miner has been working for some years. In the case of boys getting it there may be some refractive error or hereditary element. One boy I examined, aged 15, who got nystagmus after working three years, was the son of a collier who admitted having had trouble with his eyes, but had not been on compensation for it.
>
> The first stage of the disease may be called latent nystagmus. The patient may be perfectly unconscious that he has anything wrong with the eyes, although nystagmic movements may be quite obvious and definite. One case I examined for an injured back, and who then had nystagmus, worked ten months before being certified for it; another who also injured his back over two years ago has not yet been certified; so that as long as the disease remains in the latent stage, unperceived by the patient, it does not seem to interfere with his work. I do not know how long this may continue, or whether the movements are continual or only periodic.
>
> There is in many cases a general and increasing nervous irritability, and then a blow or sudden fright is sufficient to break down the coordination of the ocular muscles, and the power of accommodation to see with moving eyes is lost. The man then discovers that he has nystagmus.
>
> When the disease comes on naturally the first symptoms may be various. In some it is the lamps that seem to move or become blurred, or he becomes dazzled by them; in others headache or pain in the eyes, or else everything becomes misty and he is lost in a fog.
>
> When movements are well developed everything seems moving about, and he becomes giddy and staggers. Bending down or sudden movements increase the trouble; so does fright. A man may be able to walk about the street well enough, but if a dog barks or if some one shouts at him he is immediately lost in a fog and staggers about quite unable to see what is coming or where he is going. Hence the danger of such men working in mines.
>
> The most constant symptoms are headache, giddiness, and movements. My records are far from complete, and I find only 43 per cent with these three symptoms noted;

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[a] Elworthy, H. S., Miners' nystagmus: Brit. Med. Jour., Nov. 19, 1910, p. 1578.

but my impression is that fully 60 to 70 per cent have them all. Giddiness and movements, but without headache, also occur, and I find 7 cases with the definite record of no headache and 6 in which headache is not mentioned. Of these 13 cases, 8 were rotatory, 4 lateral, and 1 mixed.

Intolerance of light and continual headache are frequent, and in severe cases the man can sit about only with his eyes shaded and his back to the light. In such cases there may be an error of refraction as well.

One variety often passes into another, a rotatory to a lateral, or vertical to a rotatory with nictitation. Nictitation often comes on late, and may be the last objective symptom visible, but in some cases it is present early, with very indefinite movements of the eye.

The two eyes may be equally affected, or have different movements, one lateral the other vertical or rotatory, but I have never seen two eyes rotating in opposite directions.

The greatest discomfort and pain in the head is caused by the very fine and quick movements, and the least by the slower rotatory. An error of refraction may cause persistent headache, and delay recovery unless corrected by proper glasses, which, however, can not be worn in the pit.

In this connection the following observations by Shufflebotham[a] regarding the symptomatology of miners' nystagmus are of interest:

> In miners' nystagmus we are dealing not with a disease localized to the eyes, but with a general disease one symptom of which is oscillation of the eyeballs. I believe that the term "miners' nystagmus" is unfortunate, as it simply relates to one symptom of this complaint, and the symptoms are not confined to oscillation of the eyeballs and effects resulting from this phenomenon.. There may be, and generally are, symptoms such as headache, nausea, attacks of giddiness, muscular tremors, twitching of the muscles in different parts of the body, especially the muscles of the eyelids and the face and the neck; neurasthenia may be a prominent symptom, with its associated conditions, such as a quickened pulse, exaggerated reflexes, increased vasomotor irritability, sleeplessness, and nervous depression. All these symptoms may be present in any case of miners' nystagmus, but in many cases only some of them are present, and at given times the prominent symptom—the oscillation of the eyeballs—may actually be absent, although the patient is undoubtedly suffering from this disease.

VARIETIES OF NYSTAGMUS.

These observations and conclusions in a general way are confirmed by other authorities, but in the work cited they are set forth with unusual clearness and therefore are quoted in full. It also seems advisable to cite in complete detail the seven varieties of nystagmus as observed and defined by Elworthy,[b] as follows:

1. *Lateral.*—An alternating clonic spasm of the internal and external recti.
2. *Vertical.*—An alternating clonic spasm of the superior and inferior recti.
3. *Rotatory.*—An alternating lateral and vertical nystagmus in regular sequence producing rotation. In one case with a large and flaccid eye it was quite easy to see the tug of the several rectus muscles at their insertions into the globe.
4. *Mixed.*—An alternating lateral and vertical nystagmus in irregular sequence, producing rotation but irregular movements.
5. *Oblique.*—Presumably a synchronous contraction of a superior with one of the lateral recti alternating with the inferior and the opposite rectus. It could also be

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[a] Shufflebotham, Frank, Miners' nystagmus: Brit. Med. Jour., Mar. 21, 1914, p. 649.

[b] Elworthy, H. S., Miners' nystagmus: Brit. Med. Jour., Nov. 19, 1910, p. 1578.

produced by the two oblique muscles if the deviation of the axis is not corrected by the recti.

6. *Axial rotation.*—Alternating spasm of the superior and inferior obliques, with no deviation of axis. I have one case, which seems the most remarkable of the series. Coordination of the recti had not broken down, otherwise there would have been oblique nystagmus. But the only movement visible was rotation on the antero-posterior axis.

7. *Nictitation.*—Clonic spasm of the orbicularis muscle. Generally associated with some other movement, but sometimes present alone. As it occurs with considerable frequency, I think it should be classed as a variety of nystagmus.

With reference to diagnosis, he points out that this is easy enough in the majority of cases. As emphasizing, however, some of the practical difficulties of exact diagnosis, the following case is quoted in view of its bearing upon problems of workmen's compensation.[a]

I had one case of the indefinite class, who received compensation for a considerable time, and who was admitted to a hospital for some intracranial disease from which he eventually died. No nystagmus was observed while he was in hospital, but he had optic neuritis. This man was certified on subjective symptoms only. It is all very well to certify cases on subjective symptoms just because a man happens to be a collier, but it is very difficult to disprove a claim for compensation if there are these indefinite symptoms, which may, after all, have nothing to do with miner's nystagmus.

ANALYSIS OF CASES.

The results of an analysis of 100 cases are briefly summarized in the statement that the average age at the commencement of the disease was 35½ years; the average number of years a man had been working underground was 21½ years; and the average period between the first indications of nystagmus and the ultimate and subsequent leaving of work was 8 months. This average, however, included three cases with an exceptionally long duration of 2 to 8 years, and if these are excluded the average period was 6½ months. The average subsequent period of disability for all cases was 5 months, but as this included latent and uncertified cases, the average is rather an underestimate. A number of men resumed work on the surface before complete recovery. The longest period of disability was 28 months, without recovery. The shortest was 3 weeks. There were 18 latent cases, and of these, 8 first noticed nystagmus after a blow on the head; 1, after a blow on the head but without becoming aware of nystagmus until 16 months later; 5, after blows on the eye or eyebrow; 2, after blows on the back; 1, after a blow on the leg; and 1, after a sprain of his side. As regards the varieties met with, the cases were classified as follows:[b]

Of 14 cases in which nictitation was a prominent symptom, those with some other movement, such as vertical or lateral, are included in those classes, and those with no definite movement except nictitation in the indefinite. There were: Rotatory, 27 cases; lateral, 25; indefinite, 18; vertical, 12; mixed, 12; not recorded, 5; axial rotation, 1; oblique, 0; total, 100.

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[a] Elworthy, H. S., Miners' nystagmus: Brit. Med. Jour., Nov. 19, 1910, p. 1578.

[b] Elworthy, H. S., Op. cit., p. 1579.

ADEQUATE TREATMENT AND PERMANENT CURE.

Coming to the important question of prognosis, Elworthy[a] remarks that although his experience had been rather limited he found that the men who remained at work for months struggling against the disease, until finally obliged by necessity to give up their employment, required the longest time to recover, especially if advanced in years. Given a young man who has been underground for, say, 10 to 15 years, and who applies early for treatment, say, within 2 or 3 weeks after the first indications, the prognosis is distinctly favorable, but even then 2 to 4 months will be required in summer, and a longer period in winter. According to the experience had, it was found that the sooner a man with nystagmus leaves off work the better is the prognosis, but in the early stages the diagnosis is more difficult, as there may be no definite objective symptom visible.

DURATION OF DISEASE.

As regards the relation of the duration of the disease to the variety of nystagmus, it is stated that one case of axial rotation recovered in 6 weeks; 18 indefinite cases recovered in an average of 3 months; 27 rotatory cases recovered in 4½ months; 14 cases associated with nictitation, in 5 months; 25 lateral cases, in 5½ months; 11 vertical cases, in 6 months; and 12 mixed cases in 8 months. The observations had not extended over a sufficient length of time to prove whether any cases were incurable. It was also ascertained that twice as many cases recovered in the 6 months from April to September as did during the months from October to March. This variation is attributed to the fact that in summer there is more daylight, and more color about the country.

On the question of relapses, it is said that—

> One would expect that as coal mining produces the disease, so resuming work underground would produce relapses. How many of these cases will relapse, or how long it will take, I do not know. I have not had time to see yet. For the 7 cases of relapse included in the 100 the average time from resuming work to the relapse was 12 months. Two more have been observed with recurrence, but have not ceased work. One of these is now 2 years after resuming. The variety of nystagmus in a relapse is not always the same as in the first attack.[a]

SUBJECTIVE TREATMENT.

The importance of subjective treatment is first considered under preventive measures; and, second, from the strictly medical aspect. On the assumption that the direct cause of nystagmus is a complete absence of color in coal mines, the argument is advanced that[a]—

> The importance of daylight seems to have been overlooked both by the miner and the employer. I take the view that, as far as nystagmus is concerned, working underground in daytime is a mistake, as the miner in doing so loses his opportunity of

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[a] Elworthy, H. S., Miners' nystagmus: Brit. Med. Jour., Nov. 19, 1910, p. 1579.

> refreshing the eye by looking at colors in daylight, and so, in a measure, compensating himself for working by artificial light without color relief.
>
> To get this relief, the hours of work might be altered somewhat as follows:
>
> | | |
> |---|---|
> | Start work at the pit head | 4 a. m. |
> | Come out | 12 midday. |
> | Allow an hour to get home at | 1 p. m. |
> | Recreation and see the world till | 6.30. |
> | Bed | 6.30 to 2.30 a. m. |
> | Breakfast and get to pit head by | 4 a. m. |
>
> He would thus get some four or five hours of daylight all the year round, which is of far more value to the eye than artificial light.

METHODS OF IMPROVING ILLUMINATION.

It is further suggested that to prevent unnecessary fatigue to the eyes removable shades should be provided for the lamps, so that the light will be given out in the front only. Such lamps should be used in going in and out of the mines. When at the face, it is suggested the shades could be taken off, so that the light would not be interfered with. Finally, the suggestion is made that some sort of color scheme should be introduced into coal mines so as to bring about conditions as good at least as in lead mines. In brief, according to Elworthy,[a] as the essential cause of nystagmus is absence of color, the one rational preventive measure is the substitution by artifice of sufficient color to compensate for the deficiency. It is therefore proposed that the roof, the leeward sides of the posts and collars, and the cogs and sides of the alleyways be colored with some light but inexpensive wash, whitewash, or, preferably, green or other varied colors. It is realized that this would have to be done daily on account of the dust in the mine, and although this would be expensive, it is pointed out that compensation for nystagmus cases is itself a serious element of management expenses. The argument is advanced that—

> If a quarter of the sum lost through nystagmus were spent in continually coloring the mine, and was enough to bring its color relief up to the level of a lead mine, I do not see why nystagmus should not be abolished, and the other three-quarters of the loss wiped out.[b]

MEDICAL AND MECHANICAL TREATMENT.

The recommendations regarding medical treatment are briefly set forth as follows:

> The first thing to do is to remove the cause, that is, stop work underground. Let the patient rest, and in subdued light if he has photophobia.
>
> We have to deal with a state of exhaustion and increased nervous irritability. Therefore, at first medical treatment should be sedative—such as the bromides or hyoscyamus.

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[a] Elworthy, H. S., Miners' nystagmus: Brit. Med. Jour., Nov. 19, 1910, p. 1579.

[b] Elworthy, H. S., Op. cit., p. 1580.

Later these should be replaced by stimulant tonics and brighter light as he can tolerate it. To commence with stimulants seems to me like whipping up a tired horse instead of resting it.

Mechanical.—Eye shades, blue or smoked goggles, give a good deal of relief in some cases, especially in sunlight and snow, but fail in others. I should like to see other colored goggles tried, particularly green. One man recently told me that when his eyes are very painful he gets relief only on going into a green wood or field.

Proper glasses should be prescribed to correct errors of refraction.

Electrical.—I have not seen any cases that I am aware of being treated by electricity. In chronic intractable cases there seems a fair field for experiment with various forms of electrical treatment.

Special departments in hospitals.—Whether it would be profitable to provide green or other colored rooms and take in cases as patients and apply other special forms of treatment is uncertain. Very likely some way of cutting the disease short could be discovered, but, personally, I think better value for the money would be gained by the preventive measures I have indicated.[a]

NYSTAGMUS AS AN ECONOMIC PROBLEM.

This extended account of nystagmus as a practical question of mine management seems to leave little room for further discussion. The importance of any occupational disease, however, is not to be measured by its numerical frequency but by its economic effect on the working capacity of the employee. In proportion as the disease incapacitates for work, the essential and economic consequences to the workmen and to the State are a matter of most serious concern. As under modern workmen's compensation the period of incapacity involves a considerable money payment to the employee, the question is also one of serious importance to mine managers. It is largely because of workmen's compensation law that the disease has attracted so much attention in the United Kingdom within recent years. Even in so complete a treatise as the Elements of Mining and Quarrying, by Foster,[b] nystagmus is disposed of in less than eight lines. As yet most of the medical observations must be considered preliminary to a thorough, strictly scientific study of the subject. Every new contribution by a qualified medical authority adds materially to the existing knowledge of a question that is bound to assume importance in the future, not only as regards its economic aspects but even more more so from the humanitarian point of view. Observations and conclusions based on actual cases are, of course, of greater practical value than conclusions resting chiefly on theoretical considerations. Browne and Mackenzie[c] have published a review of 100 cases of miners' nystagmus, with observations on the etiology and treatment of the disease. The conclusions of these authors are briefly referred to in a reference to nystagmus in the treatise on occupational diseases by Thompson.[a] The conclusions formed by Browne and Mackenzie,[b] on the basis of 100 consecutive cases treated by them jointly, are summarized in the statement that the factors contributing to the production of nystagmus are: First, inadequate light; second, errors of refraction; third, straining of ocular muscles; and, fourth, neurotic temperament. The conclusions, in detail, are as follows:

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[a] Elworthy, H. S., Miners' nystagmus: Brit. Med. Jour., Nov. 19, 1910, p. 1579.

[b] Foster, C. Le N., The elements of mining and quarrying, 1903, 321 pp.

[c] Browne, F. J., and Mackenzie, J. R., The etiology and treatment of miners' nystagmus: Brit. Med. Jour., Oct. 5, 1912, pp. 837–840.

> 1. *Inadequate light.*—That this is an important cause of miners' nystagmus is conclusively proved by the fact that 99 per cent of our cases had been using the lock lamp for a number of years. Only one case was found where the naked light was allowed, and here the nystagmus was accounted for by hypermetropia, much straining of the ocular muscles in narrow seams, and a markedly neurotic temperament with much physical debility.
>
> The lock lamp must be 9 feet from the farthest point of the mandril, and so the workman is staring into comparative darkness, whereas the naked light is attached to the workman's cap or to a post close beside. Therefore, the naked light gives a much brighter and stronger light not only because it is exposed but also because the workman has its full benefit. We have also had experience with miners in various parts of Scotland, where the naked light is used, and in these districts miners' nystagmus is practically unknown.
>
> 2. *Errors of refraction.*—An examination of the summary of cases of miners' nystagmus seen by us will show that 90 per cent had errors of refraction, excluding the three cases in which there was evidence of error, but owing to marked photophobia no exact estimate could be made, while 7 per cent had normal refraction. Of the 90 per cent, 48 per cent had either myopic, hypermetropic, or mixed astigmatism; 27 per cent had simple hypermetropia; and 15 per cent had simple myopia. It is interesting to note that a large number of the cases of hypermetropia were those of comparatively young men who had worked only a few years at coal cutting.
>
> 3. *Straining of the extrinsic muscles of the eyeball.*—This is the result of the two foregoing factors. In all our cases the workman had his eyes fixed in a staring, strained position for long periods, either downward and laterally, as in narrow seams, or upward, as in wide seams; 90 per cent of our cases were engaged in cutting coal, while 10 per cent were haulers and timbermen, and one a colliery examiner.
>
> 4. *Neurotic temperament.*—The inability on the part of a very large number of men with nyastagmus to concentrate their physical or mental powers in any particular line of action guides us to the conclusion that such instability is probably much more the cause than the effect of nystagmus. It most certainly appears to be a weak point in the miner's armor and would repay careful examination long before the stage of inability to work.
>
> The severe headaches and aching eyes of which these men complain are accounted for by errors of refraction and straining of the eyes; the vertigo, by incoordination of the ocular muscles; the conjunctivitis and photophobia by the sudden frequent change from darkness into dazzling light.

AVERAGE AGE OF PATIENTS AND DURATION OF INCAPACITY.

An extremely interesting and useful table that is appended to the paper gives in detail the age, occupation, years underground, degree of refraction, oscillation, and the necessary explanations for 100 consecutive cases. Most of the men were miners and the exceptions are so few that it may safely be assumed that nystagmus is exceedingly rare among other underground employees. The average age was 34.95 years, the range in years being from a minimum of 18 to a maximum of 67. The average period of underground work was 19.1 years, the range in working time being from a minimum of 2 years to a maximum of 40 years. The oscillations were very slight in 2 per cent of the cases, slight in 26 per cent, marked in 48 per cent, very marked in 2 per cent, and rotatory or marked rotatory in 16 per cent. The table follows:

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[a] Thompson, W. G., The occupational diseases; their causation, symptoms, and prevention, 1914, p. 570.
[b] Browne, F. J., and Mackenzie, J. R., Op. cit., p. 837.

Details of 100 cases of miners' nystagmus.[a]

Age.	Occupation.	Time underground.	Refraction.	Oscillation.	Remarks.
		Years.			
43	Miner	Over 30	Photophobia so marked that refraction examination was impossible.	Marked	Vertigo very marked.
48	do	36	+0.75 D. sph. in both eyes	do	Nictitation and photophobia.
36	do	24	R.−1 D. cyl. horiz. L.−0.75 D. sph	Slight	Photophobia.
27	do	14	R.+1 D. L.−2.5 D. sphs	Marked	Vertigo and photophobia.
24	do	10	R.−2 D. L.−2.75 D. sphs	do	
56	do	40	R.=Normal. L.+0.50 D. sph	Slight	
29	do	16	R.−0.50 D. L.−1.50 D. sphs	Marked	Vertigo frequently.
37	do	20	R.+0.75 D. L.+1.25 D. sphs	do	Photophobia.
19	do	5	−2.50 D. horiz. cyl. in both eyes	do	
22	do	8	R. $\frac{\text{1.25 D. sph.}}{-\text{2.75 D. horiz. cyl.}}$ L. $\frac{+\text{1.25 D. sph.}}{-\text{2 D. cyl. axis } 120^\circ}$	do	Photophobia and conjunctivitis.
29	do	3	R.− 0.50 horiz. cyl. L.=normal	do	Vertigo.
39	do	27	R.+0.75 D. L.+1 D. sphs	do	Photophobia and frequent headaches.
46	do	30	R.+2 D. L.+2.75 D. sphs	do	
21	do	9	Simple hypermetropia, +6 D. in both eyes	Rotatory	Vertigo.
30	do	18	Hypermetropic astigmatism in both eyes	Very slight	Nictitation and vertigo.
46	do	30	Impossible, owing to photophobia	Very marked	
23	do	11	R.+2.5 vert. cyl. L.+0.50 D. sph	Rotatory	Severe headaches.
35	do	(b)	Hypermetropic astigmatism in both eyes	Very slight	Vertigo and aching of eyes.
28	do	13	R.+1.5 D. sph. L.+1 D. vert. cyl	Marked	
41	do	10	R.+10 D. sph. L.+10 D. sph.; 2 D. cyl	do	Nictitation and headache.
43	do	30	Oblique myopic astigmatism, −1 D. in both eyes	do	
39	do	20	R.=normal. L.+4 D. sph	Marked rotatory	Has been a hauler for last 10 years.
50	Hauler	40	R. $\frac{-\text{1 D. sph.}}{-\text{0.50 D. cyl. horiz.}}$ L. $\frac{-\text{1.50 D. sph.}}{-\text{0.50 D. cyl. horiz.}}$	Marked	Headache and photophobia.
45	Miner	34	Mixed astigmatism in both eyes	Not marked	Nictitation and vertigo.
19	do	5	Simple hypermetropia in both eyes	Marked	
21	do	9	Normal	do	Photophobia.
38	do	20	R.=normal. L.+2.5 D. sph	do	
55	do	40	Astigmatism (low degree)	Slight	
21	do	8	R.+4 D. sph. L. oblique hypermetropic astigmatism, marked	Marked rotatory	Some photophobia.
32	Timberman	12	Oblique hypermetropic astigmatism	Marked	
48	Miner	28	+2 D. sph. in each eye	Slight	Vertigo and photophobia.
35	do	22	+1.50 D. sphs. (both eyes)	Marked	Photophobia.
24	do	12	R.−3 D. cyl. horiz. L.−1.50 D. sph	do	
37	do	20	+1 D. hypermetropic astigmatism (both eyes)	Marked rotatory	
30	do	15	R.−0.75 D. L.−1 D. sphs	Slight	Severe headaches.
30	do	12	R.−1.25 D. L.−1 D. sphs	Marked	Vertigo and photophobia.
48	do	30	R.+2 D. L.+2.5 D. sphs	Slight	Photophobia.

[a] Browne, F. J., and Mackenzie, J. R., Op. cit., pp. 838–839.

[b] 8 years on coal; 4 years a timberman.

Other important results disclosed by the table can not be conveniently summarized in a statistical form.

METHODS OF PREVENTION.

The authors [a] sum up their conclusions regarding prevention in the statement that this resolves itself into medical examination of all men engaged to work underground, and the periodical examination of all underground workers for (*a*) the presence of refraction errors, (*b*) any signs of incipient nystagmus, and (*c*) physical or nervous debility. The authors emphasize the importance of adequate light, and they were surprised to find that even in the most up-to-date collieries there was, as yet, no indication of electric light being used throughout the workings. They were of the opinion that if such precautions were taken, and electric light installed in all working places in collieries, or if electric lamps capable of giving light for at least eight hours were supplied to all underground workers, miners' nystagmus would soon be unknown, and serious accidents to workmen, and consequent loss to the employer, would much more rarely occur. They overlooked the fact that electric light can not be used in gaseous mines for the essential purpose of determining the presence of fire damp.

METHODS OF TREATMENT.

The only curative treatment prescribed is rest, the use of strychnine, and the correction of refraction errors. However, the correction of refraction errors would require suitable glasses, which, of course, could not be worn underground. The conclusions are summed up briefly as follows: [b]

1. There are certain important contributory factors in the production of miners' nystagmus, such as inadequate light, refractive errors, and muscular strain.
2. Nystagmus is a menace to the miner working underground, as it may prevent the early detection of flaws in the roof, and falls may result. An illustration of the gravity of this danger is the fact that one of our cases was a colliery examiner.
3. We are convinced that the preventive and remedial measures suggested would, if carried out thoroughly, soon make miners' nystagmus a very rare complaint and greatly facilitate the detection of the small blue cap which indicates the presence of fire damp.

A PROBLEM IN WORKMEN'S COMPENSATION.

A more recent scientific study of miners' nystagmus is the lecture by Llewellyn,[c] Tyndall research student of the Royal Society, delivered at the Mining Machinery Exhibition, London, on May 31, 1913. In this address certain aspects of the disease are treated from new standpoints, and throughout the fact is kept in mind that nystagmus, because of the workmen's compensation law, is of considerable economic interest to mine owners and insurance companies. After restating the conclusions now rather generally accepted, that miners' nystagmus is an occupational disease of the nervous system and is found only among workers in coal mines, the author refers to the first case described, in Belgium in 1861, by De Conde, and then mentions the work of C. Bell Taylor, Nieden, Von Graefe, and Snell. Romiée is mentioned as having pointed out that the earliest recorded case was described in Belgium 10 years after the safety lamp had been recommended for use in that country and that it was only after the compulsory introduction of the Mueseler lamp in 1876 that an increase in the number of cases of the disease was noted. Llewellyn [a] summarizes the two principal views as regards the causation of the disease in the statement that (1) nystagmus is due to the position assumed by the miner at his work, and (2) that it is due to deficient illumination. The first view was ably and strongly advocated by Dransart, Nieden, and Snell, and the controversy of Snell with Court was referred to in the statement that Court was the first English observer to call attention to the importance of the light factor. The importance of the light factor is now accepted by practically all English observers, but on the Continent a diversity of opinion continues to prevail.

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[a] Browne, F. J., and Mackenzie, J. R. Op. cit., pp. 837, 840.

[b] Browne, F. J., and Mackenzie, J. R., Op. cit., p. 840.

[c] Llewellyn, T. L., A lecture on miners' nystagmus: Brit. Med. Jour., June 28, 1913, pp. 1359-1361.

RELATIVE FREQUENCY OF SYMPTOMS.

The lecture of Llewellyn is of unusual value, in that it includes an analysis of 600 cases. The discussion regarding the frequency of the various symptoms, and the statistical data concerning 600 cases, follow: [b]

> *Symptoms.*—The first symptom is failure of sight, especially at nighttime, or when the sufferer is called upon to perform the more skilled portion of his work. The man next complains that the lamps dazzle his eyes, and sooner or later that the lamps and all surrounding objects dance before him. Headache, varying from slight pain between the temples to attacks of extreme severity, giddiness on exertion and stooping, inability to see at nighttime, and dread of a bright light are often present.
>
> There are two distinct varieties of the disease. In the first the symptoms are absent or latent, and the man, suffering no disability, is unaware that he has nystagmus; in the second the disease is manifest and the man is more or less incapacitated, and aware that his eyes are affected. Among 750 consecutive cases, 150 latent cases were observed.
>
> The table shows the frequency of the various symptoms in the remaining 600 manifest cases.

Symptoms in 600 manifest cases.

Symptom.	Number of cases.	Percentage of 600 cases.	Symptom marked.	Symptom very marked.
Movements of objects	566	94.3	....	....
Headache	507	84.5	51	16
Giddiness	490	81.6	52	8
Night blindness	459	76.5	4	....
Dread of light	284	47.3	10	....

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[a] Llewellyn, T. L., Op. cit., p. 1339.

[b] Llewellyn, T. L., Op. cit., p. 1359.

The physical signs are briefly stated to be involuntary and irregular movements of the eyeballs, chiefly of a rotatory character, tremor of the eyelids, eyebrows, head, and, in some cases even of the neck and shoulders. There is also often a backward inclination of the head with drooping eyelids. Reference is made to a recent attempt to describe a condition in which miners' nystagmus could exist without the presence of nystagmus proper, or, in other words, where the oscillation of the eyeballs would be replaced by a blinking of the eyelids; this question has not been settled, but it was at the time under consideration by a departmental committee. The numerical frequency of the disease, which, according to foreign authors, runs from 5 to 20 per cent of all workmen underground, is shown in a table of the certified cases according to the workmen's compensation act for the years 1908–1911, as follows:[a]

Frequency of disablement.

Year.	Number of certified cases.	Proportion of cases to underground workers.
		Per cent.
1908	460	0.06
1909	1,011	.23
1910	1,618	.19
1911	2,519	.29

INCAPACITY FOR WORK CAUSED BY NYSTAGMUS.

The results of Llewellyn's inquiry regarding incapacity for work resulting from nystagmus are summarized in the following statement:[a]

> Slight cases can soon return to work underground; ordinary cases can return after an interval of surface work of 3 to 12 months. Although one attack of nystagmus predisposes to another, I think it only fair to allow a man to try to regain his income by working underground again if possible. The exceptional cases should not return to work underground, and by exceptional cases I mean the following: Men who have failed to work several times before, very young lads, old men with commencing cataract, men with high degree of refractive error, and those cases which have been of exceptional severity. The following table was taken from returns, extending over four years, from five large colliery companies employing over 28,000 men:

Back at old work	152, or 45 per cent.
Left employ or commuted	9
At surface work	105
Idle	73

MINE DANGERS RESULTING FROM NYSTAGMUS.

In reply to the important question as to whether it is dangerous to employ a man on the ground that he has once suffered from nystagmus, Llewellyn[a] comments as follows:

> In the first place, is the man more liable to accident? It is very difficult to answer this question. Men are often sent out of the pits by managers from fear of this danger,

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[a] Llewellyn, T. L., A lecture on miners' nystagmus: Brit. Med. Jour., June 28, 1913, pp. 1359–1361.

> but this is when they are about to fail on account of the disease. I think it probable that many slight accidents are due to nystagmus, but I have only once had a complaint from a man that his accident was directly due to his nystagmus. There is, however, the possibility of a greater danger, namely, that a catastrophe may result from the failure of a fireman or collier suffering from the disease to detect the presence of gas. The table given below shows the results of tests made on all the firemen of five large collieries. The tests were made on the surface with the help of an Oldham gas-testing chamber. The men were first examined for the presence of nystagmus, and then tested independently for their ability to detect the cap given in the presence of gas.

The evidence to substantiate the foregoing conclusions is set forth in the table below:

Results of examination of miners for ability to see gas cap.

Condition of miner.	Number of men tested.	Number giving correct estimate.	Quantity of gas shown by cap.					
			Trace.	1 per cent.		2 per cent.		3 per cent.
			Failed.	Failed.	Underestimated.	Failed.	Underestimated.	
Normal........	49	28	14	4	9	....	14	Seen by all, but frequently underestimated.
Nystagmic.....	41	4	19	10	18	6	12	

The table shows that all the men examined were able to detect the presence of gas when 3 per cent was in the chamber; but the nystagmic cases are shown to have been responsible for more mistakes than were made by men not afflicted with the disease.

DETAILS OF ENGLISH EXPERIENCE.

The statistical results of the analysis are, in brief, that the mean age was 39.84 years and the mean number of years of underground life was 25.58 years. These averages should be compared with the analysis of 100 cases by Browne and Mackenzie and of another 100 cases by Elworthy. The occupations of 685 cases were given, but underofficials were excluded. It was brought out that although all classes of workmen were affected, the great majority of the men were employed at the face of the mine. Out of 685 cases of all underground employees 557, or 81.3 per cent, were either miners or mine laborers employed as fillers or loaders. The number of timbermen and repairers suffering from nystagmus was 52, or 7.5 per cent, and the number of haulers or trackmen was 40, or 5.8 per cent. Other occupations represented were: Rippers, 8; laborers, 6; contractors, 5; underofficials, 3; and hitchers, engine drivers, hostlers, and masons, 1 each. This analysis does not show clearly what is meant by the previous statement, as given in the lecture, that underofficials were not considered.

As regards the method of getting coal and its relation to nystagmus, it is pointed out that although many authors hold undercutting with a pick to be the chief factor in the production of the disease, the following analysis is based on answers given by 580 nystagmus cases who either were or had been miners. Much holing, or undercutting, accounted for 177 cases and some holing for 171, or a combined total of 348 cases, or 60 per cent. In 40 cases the men had done little holing and in 192 cases no holing, or a combined total of 232 cases, or 40 per cent. In further explanation of this point it is stated[a] that:

> Colliers in Somerset, Forest of Dean, and in the house coal pits of South Wales all get their coal by bottom-holing, yet nystagmus is very rare in these pits. The collier when holing is supposed to direct his eyes obliquely upward, and the advocates of the old school say that nystagmus results from the strain produced by this unnatural position of the eyes; but does a collier look obliquely upward when he holes? A collier looks upward when engaged in top-holing, but not when he holes in the bottom. The eyes are then either directed straight forward or a little downward. A little consideration will show that the swing of the pick will be more powerful and complete when the blow is ended below the level of the eyes.

RELATION OF NYSTAGMUS TO THICKNESS OF SEAMS WORKED.

The bearing of the thickness of the seams in which miners work on the relative frequency of nystagmus was inquired into, but the results of the investigation were seemingly negative. The results are summarized in the table below:[b]

Relation of thickness of seams to frequency of nystagmus.

Thickness of seam.	Number of cases of nystagmus.
Less than 2 feet	1
2 to 3 feet	47
3 to 4 feet	133
4 to 5 feet	148
5 to 6 feet	115
6 feet and over	141

On the important question of illumination it is stated[b] that:

> In metalliferous mines candles or open lamps are used, while in a coal mine safety lamps are often necessary. The naked-light coal mine comes midway between the safety-lamp coal pit and the metalliferous mine, having the general blackness of the former and the good light of the latter. Manifest nystagmus is common in the safety-lamp coal pit, rare in the open-light coal pit, and unknown in the metalliferous mine. Nystagmus is practically unknown in the purely naked-light districts of Somerset and the Forest of Dean and is rare in the open-light pits of South Wales. In South Wales most of the men had worked at one time or another with lamps, and it is common for the men to continue working in an open-light pit after they have failed to work with lamps. Taking into consideration the number of men employed, England and Wales, using safety lamps three times more frequently than Scotland, had four times the number of cases of nystagmus in 1910.

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[a] Llewellyn, T. L., A lecture on miners' nystagmus: Brit. Med. Jour., June 28, 1913, p. 1360.

[b] Llewellyn, T. L., Op. cit., p. 1359-1361.

SAFETY LAMPS AND INADEQUATE ILLUMINATION.

Of the number examined, 741 men had used safety lamps, and 723 of these had used such lamps almost exclusively. Only 9 of the men suffering from nystagmus had worked with candles alone. As the result of a special investigation in South Wales, the data summarized in the tables below were obtained.[a] The facts are of special interest in that the number of men working in both classes of mines was known and the illumination at the coal face had been tested.

Number of cases of nystagmus and average mine illumination.

Working place.	Relative proportion of certified cases of nystagmus to men employed.	Average illumination at coal face.
	Per cent.	*Foot candles.*
Safety-lamp pit	6.3	0.008, or 1
Candle pit	1	.09, or 5

The conclusion is therefore advanced that in the same district the incidence of nystagmus was found to vary inversely with the candlepower of the lamps used. This important and far-reaching conclusion is sustained by the next table,[a] which gives the number of cases of nystagmus, together with the number of men employed and the candlepower of the lamps:

Comparison of number of nystagmus cases and candlepower of lamps used.

Pit.	Number of men employed.	Number of cases of nystagmus.	Rate per 1,000 employed.	Candlepower of lamps.
A	450	9	20.0	0.235
B	1,400	22	15.7	.27
C	1,500	10	6.7	.33
D	2,500	14	5.6	.4
E	1,900	8	4.2	.42

I have included in this table a new column, showing the nystagmus rate per 1,000, to facilitate a more precise comparison of the different groups.

The relative efficiency of different types of lamps and their relation to nystagmus is discussed at some length in Weyl's treatise on industrial diseases,[b] which includes a reference to the Pollak lamp, with illuminating power of 0.9 of normal candlepower. Weyl is of the opinion that the only hope for relief lies in the direction of a material improvement in the illuminating efficiency of the existing types of safety lamps.

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[a] Llewellyn, T. L., A lecture on miners' nystagmus: Brit. Med. Jour., June 28, 1913, pp. 1359–1361.

[b] Weyl, T., Handbuch der Hygiene, Jena, 1897, pp. 284–285.

DIFFERENTIAL FACTORS OF ILLUMINATION.

Llewellyn continues his interesting discussion by a careful consideration of the differential factors of illumination at the coal face, which in the main consists (1) of the candlepower of the source of light used; (2) the distance at which this light has to be placed from the coal face; (3) the character of the surroundings, and (4) the composition of the air at the coal face. In some detail these points are discussed as follows:[a]

1. The candlepower of the wax candles used in mines is generally equal to one standard candle, but the tallow candle may be equal to two. The oil safety-lamp rarely gives more than one-third of a candlepower at the coal face when clean and much less when dirty. Some dirty lamps have given only one-tenth of a candlepower.
2. The candle can be placed close to the coal face, but the lamp must be placed out of danger and is always much farther from the coal face. As the intensity of illumination varies inversely with the square of the distance, the advantage of the candle is very great.
3. In the coal mine practically all the incident light is absorbed and the advantage of reflected light is lost. We do not realize how much of the lighting of interiors is due to this reflected light, but the difference between a room papered with light paper and one with a dark red paper is very obvious.
4. The light of a safety lamp diminishes when the oxygen percentage of the air falls and the presence of moisture has the same effect. The presence of gas up to 4 per cent increases the luminosity of the flame. So accurately does the safety lamp answer to the various changes in the atmosphere that a rough estimate of the oxygen percentage might be calculated by taking photometric readings of a standard oil lamp first under normal conditions and then in the different districts of the mine.

The scientific thoroughness of the investigation is further emphasized by an analysis of the amount of light falling on the coal face in a number of mines. In five open-light mines the average illumination at the coal face was 0.09 foot candle, against an average illumination of only 0.018 in eight safety-lamp mines, or only about one-fifth of that in an open-light mine. The relation of the amount of holing done .combined with different kinds of illumination on the prevalence of nystagmus is further shown in the form of a table, which fully sustains previous conclusions.[b]

Bearing of amount of holing combined with different kinds of illumination on the prevalence of nystagmus.

District.	Amount of holing.	Position of miner at work.	Thickness of seam.	Character of illumination.	Prevalence of nystagmus.
			Feet.		
Somerset	Much	On side	1½ to 3½	Candles	Unknown.
Forest of Dean	do	do	2 to 4	do	Do.
Open-light pits, South Wales	do	On side or knees.	2½ to 5	do	Rare.
Safety-lamp pits, South Wales	None	On knees or standing.	3½ to 6	Safety lamps.	Common.
Midlands	Much	On side	5 to 7	Lamps	Do.

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[a] Llewellyn, T. L., A lecture on miners' nystagmus: Brit. Med. Jour., June 28, 1913, pp. 1359-1361.
[b] Llewellyn, T. L., Op. cit., p. 1361.

VISUAL DEFECTS AND EYE ACCIDENTS.

Aside from the mechanical factors influencing the rarity or frequency of nystagmus, the personal factor requires to be taken into account. Llewellyn[a] points out that the importance of the personal factor is now recognized by a large number of surgeons and that ocular defects play an important part in determining whether a man should have nystagmus. He sums up his own investigations in the statement that, aside from 225 negative cases which either were not examined or were obviously in too bad a condition to admit of a test, there were only 95 cases of normal vision. The number of men with serious errors of refraction was 430, or 81.9 per cent of the cases examined. The kinds of visual impairment were as follows: Hypermetropia, 170; myopia, 57; and astigmatism, 203. It is properly pointed out that a small error of refraction is common in normal persons, and furthermore that accidents and ill health are also determining factors. These observations, however, do not detract from the profoundly significant statement that, underlying the mechanical problem of defective illumination is the equally important question of fundamental errors of refraction, for which there is only one remedial agency known, and that is suitable glasses, which can not very well be worn underground. Accidents and ill health, however, are of sufficient importance to require some consideration, and according to the present investigation in 146 cases there was a previous history of an accident, in 73 cases to the eye, in 43 cases to the head, and in 30 cases the injuries were general. In North Staffordshire, it is further stated, accidents to the eye occur frequently before the onset of nystagmus. In the first 600 cases examined there was a history of accidents to the eyes in 36 cases, and in the last 150 cases, all from North Staffordshire, there had been injuries to the eyes in 37 cases, or 24.7 per cent. The final observations by Lewellyn[b] have reference to preventive treatment, and are briefly summarized as follows:

> It is in the first place necessary to improve the miners' lamp, and the mining engineer must no longer be content with an average illumination of one-fiftieth of a foot candle at the coal face. The introduction of electric lamps into general use is probable, as it seems unlikely sufficient light can be obtained in any other way. The elimination of unfit workmen by medical examination before employment would also be of the greatest service. Efficient ventilation and any hygienic measures will also help.

ESTIMATE OF NYSTAGMUS IN THE UNITED STATES.

The statistical application of the foregoing considerations to the coal-mining industry of the United States is rather limited at present. No trustworthy data exist which warrant more than an approximate estimate of the probable number of nystagmus cases among American coal miners. According to the statistics of the Bureau of Mines the number of men employed underground is estimated at 596,470 for the year 1913.[a] As the average rate of new cases of nystagmus reported under the British workmen's compensation act during the five years ended with 1912 had been 9.2 per 10,000 employed, this rate, when applied to the total number of persons employed in coal mining in the United States in the year 1913, given by the Bureau of Mines as 747,644,[b] would indicate the possible, if not probable, existence of 688 new cases of nystagmus per annum. As the cumulative rate of old and new cases under the English experience by the year 1912 had reached 29.8 per 10,000, this would indicate a possible, if not the probable, number of persons employed in American coal mining and affected with nystagmus as numbering 2,228 for the year 1913. These rates are unquestionably conservative, for they are far from the 5 per cent of ascertained cases for certain mining districts of Germany. If the proportion of American coal-mine employees affected with nystagmus were as high as 5 per cent, the number of such cases estimated for the year 1913 would be 37,382.

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[b] Llewellyn, T. L., A lecture on miners' nystagmus: Brit. Med. Jour., June 28, 1913, p. 1361.

[a] Llewellyn, T. L., Op. cit., pp. 1359-1361.

NYSTAGMUS STATISTICS OF THE UNITED KINGDOM.

The table following exhibits the cases of nystagmus among miners in the United Kingdom who received compensation under the workmen's compensation act during the five years ended with 1912. The number of coal miners has been derived from the annual reports of the chief inspector of mines and quarries, and the number of new cases, and new and old cases combined, from the annual statistics of the operations of the workmen's compensation act.

Cases of miners' nystagmus compensated for under the workmen's compensation act, United Kingdom, 1908–1912.[c]

Year.	Number of coal miners.	Data on nystagmus.			
		Number of new cases.	Rate per 10,000 coal miners.	Number of old and new cases.	Rate per 10,000 coal miners.
1908	972,232	386	4.0	460	4.7
1909	997,708	631	6.3	1,011	10.1
1910	1,032,702	956	9.3	1,618	15.7
1911	1,049,897	1,374	13.1	2,518	24.0
1912	1,072,393	1,376	12.8	3,195	29.8
Total	5,124,932	4,723	9.2	....	....

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[a] Fay, A. H., Monthly statement of coal-mine fatalities in the United States, October, 1914, with revised figures for preceding months: Bureau of Mines, 1915, p. 21.

[b] Fay, A. H., Loc. cit.

[c] From the annual reports of the chief inspector of mines and quarries.

The table emphasizes the importance of miners' nystagmus as an occupational disease. This aspect of the problem is briefly reemphasized in the following introductory remarks to an extended address on miners' nystagmus in a course of lectures delivered before the Royal College of Physicians of London by Shufflebotham:[a]

> Miners' nystagmus must be regarded as the commonest of all occupational diseases. This may be due to the fact that the mining industry is, after agriculture, the largest industry in the country. In my opinion the number of cases of miners' nystagmus far exceeds the numbers which would be given in compensation statistics, which take account only of cases in which undoubted incapacity for work has been produced, and not of the much larger numbers of early cases in which the patients are able to continue in their employment.

NYSTAGMUS AS AN INDUSTRIAL DISEASE.

The subject of nystagmus is referred to for the first time at some length in the home office report on the statistics of compensation for the year 1912.[b] An extract follows:

> The figures for nystagmus are remarkable. In the first full year (1908) during which the new provisions as to industrial diseases were in operation, the number of nystagmus cases was 460 (of which 386 were new cases and 74 continued from the last half of 1907); 380 of these cases were continued into 1909, and 631 new cases arose, or 1,011 cases in which compensation was paid in 1909; 662 of these were continued into 1910, and 956 new cases arose, making a total of 1,618 cases in 1910; 1,144 were continued into 1911, and 1,375 new cases arose, making a total of 2,519 in 1911; 1,819 cases were continued into 1912, and 1,376 new cases arose, making a total of 3,195 in 1912. In 1908 the remedy was still probably unfamiliar, but a comparison of 1912 with 1909 shows that the number of new cases arising annually has more than doubled. The 1912 figures, however, show that the growth in the number of new cases has stopped for the present. What is perhaps more important is that the figures of "continued cases" show that the proportion of long-continued disablement cases is very high; the number of cases continued from 1911 to 1912 greatly exceeds the number of new cases that arose in 1911. It is evident that the adoption of means to prevent the occurrence of this disease, which the most recent investigations attribute to insufficiency of the light by which miners do their work, is becoming a matter of importance to the employer.

The report states that during 1913 there was a further increase in the number of new cases of nystagmus, the statement in the report[c] being as follows:

> As regards nystagmus, attention was drawn, in the corresponding section of the introduction to the statistics for 1912, to the remarkable increase which has occurred each year since 1908 in the total number of cases of this disease in which compensation has been paid, but it was noted that in 1912 the growth in the number of new cases had, for the time being, stopped. The figures for 1913, however, show again a striking increase both in cases continuing from the previous year and in new cases.

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[a] Shufflebotham, Frank, The hygienic aspects of the coal-mining industry in the United Kingdom: Brit. Med. Jour., Mar. 21, 1914, p. 648.

[b] Statistics of compensation and of proceedings under workmen's compensation act, 1906, and the employers' liability act, 1880, during year 1912, London, 1913, p. 9.

[c] Loc. cit.

ESTIMATE OF COMPENSATION COST.

It is regrettable that the statistics for nystagmus should not be given in sufficient detail as regards the total and average amounts paid in compensation and the average duration of the illness. As the large majority of cases of compensation on account of industrial diseases in the mining industry of Great Britain were for nystagmus, it would seem reasonably safe to apply the figure thus obtained to the cases compensated for during the year 1912. The average amount paid in compensation on account of nonfatal cases of industrial disease in the mining industry was £14.43 ($70.22). If this amount is applied to the 3,195 cases compensated during the year, the approximate total cost of workmen's compensation on account of nystagmus in the United Kingdom for the year 1912 was $224,353. If the same amount were applied to the estimated number of nystagmus cases in the United States (2,228), the corresponding amount for the year 1913 would be $156,450.

CONCLUSIONS OF COMMITTEE ON INDUSTRIAL DISEASES.

A full discussion of the compensation paid to workmen for nystagmus is contained in the first report of the Departmental Committee on Compensation for Industrial Diseases.[a] In that investigation it was emphasized that the burden of proof should rest on the employer, that the disease was caused by insufficient light and also by the strained position of the head and eyes, that the diagnosis was fairly easy but that the first stage of the disease might easily be ignored, that complete incapacitation from the disease was rare, so that malingering was both possible and seemingly not uncommon. It was furthermore brought out that the proclivity to the disease was incurable, that the proportion of colliers affected was held by different witnesses to be rather variable. A rest or change of occupation was considered necessary for a cure, the burden of responsibility being placed upon safety lamps producing inadequate illumination. Upon the basis of the data procured the committee recommended that miners' nystagmus be added to the schedule. As their observations on the subject are of historical and practical interest they are given in full as follows:[b]

Nystagmus.—This disease is prevalent among miners in certain districts, especially where the coal seams are thin. It is due primarily to fatigue of the elevator muscles of the eyes from the constrained position, in an oblique upward direction, in which the eyes have to be kept. Insufficiency of light from the lamp would appear to be a secondary but not inconsiderable cause. The miner mainly affected is the hewer who works at the coal face, but deputies in low seams, the on-setter in charge of the cage, and others also, may, and do, suffer. The objective symptom is an oscillation of the eyes (nystagmus), the rate varying from 100 to 300 times per minute, and associated with it subjectively are headache, giddiness, and dancing of objects before the eyes, which cause frequently much discomfort and occasionally incapacitate the miner entirely from work. The malady, as a rule, does not occur under 30 years of age, and rarely until after 10 years from commencement of work. Recovery may be expected on cessation from pit work in 3 to 12 months' time, but long before this, in a few weeks, in the majority of cases, work not involving the particular eye strain is possible. Cases of nystagmus, as regards degree of incapacity, were classed for us by Dr. Meighan, surgeon to the Glasgow eye infirmary, in three groups: (1) those in which the patients are slightly affected and do not cease work; (2) those in which the oscillation is accompanied by giddiness, and where the men have to leave off their particular work underground; and (3) those where the men are obliged to cease work altogether. He considered that 5 per cent of men employed in mines would represent the number who sought treatment under one or other of the three classes, but that the first class would embrace most of the cases. The weight of evidence, however, was strongly in favor of the view that no matter what stage nystagmus might have reached when medical advice for symptoms due to it was sought, pit work should be entirely relinquished on the ground that this course alone would prevent aggravation. This view was expressed notwithstanding the fact that miners who had undergone treatment for nystagmus five or six years previously and been cured, were known to have resumed their ordinary work again and continued in it without, so far as the witnesses knew, further injury. The data on which this medical practice is based do not appear to us, from the evidence, to be entirely conclusive, and in some cases, perhaps, the advice appears to have been given as the result of dogmatic statements made on the subject rather than of actual experience. The importance and far-reaching character of this medical conclusion will at once be apparent, when it is remembered that the most prominent point brought out by the evidence in regard to the disease was that, although its existence can be easily diagnosed, the symptoms are largely subjective, and there is no necessary relation between the severity of the disease and the degree of incapacity. In other words, one man may exhibit a very marked oscillation of the eyes, and yet suffer little discomfort, and be able and willing to continue at his work; another may show overt symptoms less acute, and yet may claim, and claim truly, that he is incapacitated from his usual employment. This fact may perhaps give rise to difficulty in settling disputed cases of compensation. But since the only prospect of curing nystagmus is for the sufferer to abandon, if not altogether, at least for a time, employment below ground in badly lighted mines, it is clear that nystagmus may furnish a legitimate ground for compensation, even if the overt symptoms are comparatively slight. For the patient, though he may not at the time be actually unable to continue his work, ought to discontinue it if he is not to get worse; and if the result is that, under medical advice, he has to accept employment above ground at a lower wage, he is, in the words of the act, "disabled * * * from earning full wages at the work at which he was employed."

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[a] Report of the Departmental Committee on Compensation for Industrial Diseases, London, 1907, pp. 21-22, 159-161, 402-403.

[b] Op. cit., pp. 9-10.

MALINGERING.

The question of malingering, on the alleged ground of incapacity from nystagmus, is one of considerable importance. As observed by Oliver:[a]

> The symptoms are entirely subjective, and there is no necessary relation between the severity of the oscillation and the degree of incapacity for work. Miners' nystagmus has been scheduled for compensation, but the fact just alluded to is sure to raise difficulties in settling disputed cases of compensation, since one coal miner may suffer little, although the subject of marked oscillation of the eyes, while another with less prominent signs may experience so great discomfort as truly to unfit him for work.

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[a] Oliver, Thomas, Diseases of occupation, London, 1907, p. 274.

A review of the literature on malingering fails to sustain the conclusion that the tendency to obtain compensation by fraud on account of impairment due to nystagmus is at all common. The most recent work, by Collie,[a] mentions only two cases, which are not applicable to the present discussion.

There are also no references thereto in the treatise by Harbaugh.[b]

CLONIC SPASM OF THE EYELIDS.

There is a reasonable chance of confusing clonic spasm of the eyelids with nystagmus, a matter that was rather fully considered in a special report of the Departmental Committee on Compensation for Industrial Diseases.[c] It is observed in this report that—

> The necessity for some investigation concerning clonic spasm of the eyelids (that is, spasmodic contraction and relaxation of the muscles of the eyelids) was indicated by suggestions that miners suffering from such spasm had been refused certificates of compensation because they did not exhibit the symptom nystagmus (that is, oscillation of the eyeballs), though the disease nystagmus was already scheduled by the Secretary of State's order of the 22d of May, 1907. The inquiries subsequently made by you of ophthalmic specialists and others had revealed considerable divergencies of experience and opinion as to the existence and nature of such a spasm, particularly to a disabling extent, apart from nystagmus; some authorities suggested that it was a variety of nystagmus, others that it was at any rate a symptom of that disease, and others that it was merely a habit. The questions involved were therefore referred to this committee.

The subject of clonic spasms of the eyelids is briefly referred to by Shufflebotham,[d] as follows:

> Clonic spasm of the eyelids is a common and in some cases the most prominent objective symptom. Sometimes it is an early, sometimes a late symptom, and very often it may remain after the oscillation of the eyeball has ceased. Llewellyn has pointed out that the movements of the eyelid associated with nystagmus are of two kinds, the coarse blinking movement and the fine tremor or clonic spasm, and in the former, although the movements may be quick, they are tonic and not clonic in nature. The rapidity of the clonic movements may exceed 100 a minute, and in some cases the movements may be so quick that it is impossible to count them. These movements may be exaggerated and made more obvious by adopting the same means as in oscillation of the eyeballs.

After considering all the evidence available the committee[e] came to conclusions as follows:

> We find that the word "nystagmus" is no more than the name of a symptom, and can not conveniently be employed to name a disease. It denotes only oscillation of the eyeballs. "Miners' nystagmus," on the other hand, is a term well understood to name a disease or group of symptoms, practically confined to miners, of which oscillation of the eyeballs (that is, "nystagmus") is the commonest, but not invariably pres-

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[a] Collie, John, Medico-legal examinations and the workmen's compensation act, 1906, London, 1912, 128 pp.

[b] Harbaugh, C. H., Causes of disability, 1909, 650 pp.

[c] Report of the Departmental Committee on Compensation for Industrial Diseases, London, 1913, p. A2.

[d] Shufflebotham, Frank, Miners' nystagmus: Brit. Med. Jour., Mar. 21, 1914, p. 650.

[e] Report of the Departmental Committee on Compensation for Industrial Diseases, London, 1913, p. A3.

ent, objective sign. This disease has many symptoms, some subjective and some objective. We have no doubt that during its course, at some time or other, the symptom nystagmus appears in all cases. That is the conclusion we have come to on the evidence of those who have had the greatest experience, but we can not deny that, among those we heard, much diversity of opinion was expressed as to whether it is present at all times, or even susceptible of elicitation by repeated tests under conditions favorable to its perception. And, in some cases, accompanying it, or in others even replacing it in the later stages, may be clonic spasm of the muscles of the eyelids. Consequently the symptom nystagmus, however easily found in a great majority of cases, ought not in all to be taken as a conclusive test either of the presence or of the absence of a disease of which, after all, it is but one symptom. We find further that the suggestion that it has been taken as such a test is not altogether unfounded. We are satisfied that cases of miners' nystagmus may have been wrongly diagnosed, and that certificates of disablement are likely to be refused, through too much insistence on this one test; and we are convinced that it is necessary to make it abundantly clear to all those concerned in the administration of the act or in the diagnosis of cases that the condition, the existence or nonexistence of which to an incapacitating extent is to determine the question whether there can be a claim to compensation, is not the symptom nystagmus alone but the whole disease known as "miners' nystagmus." We also find that it is not sufficient and for various reasons would not be proper merely to call attention also to the additional symptom clonic spasm; all the symptoms, whether subjective (for example, movements of objects, headache, giddiness, night blindness, and dread of light) or objective (for example, movements of the eyeballs, tremor of the eyelids, eyebrows, head, and even of the neck and shoulders) must be taken into account. The question for decision is: "Do the symptoms present in this individual, the objective symptoms and the subjective symptoms taken together, with or without the history of the case and the other available evidence, show that he has miners' nystagmus to such an extent that he is wholly or partially incapacitated within the terms of the act."

As regards the point raised in McGinn *v.* Udston, we find that the word "nystagmus," being only the name of a symptom, either names no disease at all and so gives no title to compensation, or (and this is the interpretation on which the court acted) includes nystagmus even when it is a symptom of forms of disease (for example, Friedreich's ataxia, disseminated sclerosis, and tumor of the cerebellum) that are not industrial.

In view of the evidence given to us and the facts disclosed by recent researches as to the causation of miners' nystagmus by inadequate illumination at the coal face and elsewhere in the mine, we entertain the gravest doubt whether true miners' nystagmus can ever occur in persons other than miners. The committee of 1907, however, seem to have had such cases in mind (for though in the body of their report they referred to "miners' nystagmus," in their recommendation they spoke only of "nystagmus"). We are therefore of opinion that any amendment of the existing schedule should be so framed as to preserve the existing claim to compensation for cases of miners' nystagmus in persons other than miners, if such cases occur.

The "minutes of evidence"[a] are of unusual value, including observations on the predisposition to miners' nystagmus, causation, and its occurrence in nonminers as well as its practical limitation to persons employed in the coal-mining industry. The symptoms are fully discussed, and the evidence collected on some points is rather technical. Clonic spasms of the eyelids by some witnesses was not considered a separate disease. Its connection with conditions other than miners' nystagmus, and its differentiation from other forms of blinking, were fully brought out. The subject of incapacitation by miners' nystagmus was considered, as was the subject of symptoms, as well as the chances of simulation or malingering and the risk of recurrence.

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[a] Report of the Departmental Committee on Compensation for Industrial Diseases, London, 1913, pp. 82-87.

CONCLUSIONS.

In view of the foregoing, it would seem extremely improbable that an occupational affliction so well defined should be wholly absent in the coal-mining industry of the United States. General investigations are not likely to yield useful results, but specialized inquiries should be directed exclusively to underground employees in mines using exclusively or extensively safety lamps as a precaution against mine explosions. Even though some of the apparent increase in the frequency rates of nystagmus for the United Kingdom be attributed to malingering because of the compensation paid on account of incapacity for work, it would seem reasonable to suppose that more cases of malingering or fraud would have been reported than are shown by the available records. The economic importance of nystagmus as shown by German data is set forth in a summary statement, derived from the statistical reports of the Bochum Miners' Union,[a] exhibiting the proportion of compensated nystagmus cases in the invalidity cases due to all causes, by divisional periods of life.

Invalidity cases on account of nystagmus in the Bochum Miners' Union, 1908–1912.

Age groups of miners.	All invalidity cases.	Nystagmus cases.	Invalidity due to nystagmus.
Years.			*Per cent.*
Up to 20	330	....	....
21–25	790	49	6.2
26–30	1,713	280	16.3
31–35	2,691	718	26.7
36–40	2,660	784	29.5
41–45	2,324	705	30.3
46–50	2,766	539	19.5
51–55	2,866	269	9.4
56–60	1,836	76	4.1
61–65	724	11	1.5
66–70	164	2	1.2
Over 70	39	....	....
Total	18,903	3,433	18.2

It is shown by this table that of all the invalidity cases on account of which compensation was paid, 18.2 per cent were the result of nystagmus. The actual number of such cases was highest at the ages of 36 to 40, and the relative proportion was highest at the ages of 41 to 45. It has not been feasible to reduce these cases to the basis of a rate per 1,000 employed, by divisional periods of life, but the above table is entirely conclusive evidence that nystagmus is largely an affection of coal miners at the age of 31 to 50 years, when 19.5 to 30.3 per cent of all invalidity requiring compensation is due to this single and well-defined specific cause of disablement.

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[a] Allgemeiner Knappschafts Verein zu Bochum.

The relative frequency of the disease in the Bochum mining district is a matter of considerable practical importance. It may be questioned whether the subject has anywhere else received such extended and strictly scientific consideration. The activities of the Bochum Miners' Union are confined chiefly to the administration of the sick fund and of the invalidity insurance fund. The number of cases of nystagmus to which the sick fund was applied during the period 1905–1913 are shown in the following table:[a]

Number of cases of miners' nystagmus to which sick fund of Bochum Miners' Union was applied, 1905–1913.

Year.	Members in union.	Cases of miners' nystagmus.	Nystagmus cases per 1,000 members.
1905	269,000	970	3.61
1906	286,000	903	3.16
1907	309,000	1,098	3.55
1908	343,000	818	2.38
1909	348,000	1,333	3.83
1910	351,000	1,225	3.49
1911	357,000	1,371	3.84
1912	376,000	1,510	4.02
1913	409,000	742	1.81
1905–1909	1,555,000	5,122	3.29
1910–1913	1,493,000	4,848	3.25

These figures show that during the last four years covered by the table the average nystagmus rate has been practically the same as during the first five years covered; but that although the rate during 1912 was the highest on record, or 4.02 cases per 1,000 members exposed to risk, the rate for 1913 was only 1.81, or the lowest on record during the nine years under observation. The actual number of cases during 1913 was almost exactly one-half of the number requiring the application of the sick fund during 1912. However, the medical report of the Bochum Miners' Union for 1913[b] explains that the reduction is not to be explained on account of a diminished frequency, but in conformity with a decision of the superior court that only the most serious cases of nystagmus were to be considered entitled to compensation in the future.

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[a] Verwaltungs-Berichte, Allgemeiner Knappschafts Verein zu Bochum, 1905-1913, Bochum, Germany, 1906-1913.

[b] Vol. 1, p. 146.

Much the same result is obtained by an analysis of the invalidity cases to which the fund was applied during the same period, as shown by the following table:[a]

Number of cases of miners' nystagmus to which invalidity insurance fund of Bochum Miners' Union was applied, 1905–1913.

Year.	Members in union.	Cases of miners' nystagmus.	Nystagmus cases per 1,000 members.	Cases with secondary complications.	
				Number.	Per cent of nystagmus cases.
1905	263,000	463	1.76	107	23.1
1906	280,000	590	2.11	126	21.3
1907	301,000	432	1.43	72	16.7
1908	332,000	406	1.22	43	10.6
1909	340,000	757	2.23	61	8.1
1910	341,000	824	2.42	105	12.7
1911	348,000	797	2.29	73	9.2
1912	367,000	649	1.77	78	12.0
1913	396,000	195	.49	30	15.4
1905–1909	1,516,000	2,648	1.75	409	15.4
1910–1913	1,452,000	2,465	1.70	286	11.6

According to this table the invalidity rate on account of miners' nystagmus was 1.75 per 1,000 during the first 5 years and 1.70 per 1,000 during the last 4 years covered by the table. The reduction in the number of cases during 1913 is even more marked as regards invalidity cases than as regards sickness cases. The table includes a column showing the cases of nystagmus with secondary complications, and the proportion of such cases to the total number of miners entitled to invalidity annuities on account of temporary or permanent wage-earning incapacity as a result of nystagmus. The percentages show a wide range, from a minimum of 8.1 in 1909 to 23.1 in 1905. The percentages, of course, would be affected by special causes such as, for illustration, bronchial catarrh, pneumonia, and other respiratory diseases influenced by season. Out of a total of 5,113 cases of miners' nystagmus during 1905–1913, 695, or 13.6 per cent, were complicated by other causes or diseases, as follows: Other eye diseases, 262, or 5.1 per cent of the total number of nystagmus cases; other diseases of conjunctive tissue membrane and eyelids, 68, or 1.3 per cent; pulmonary emphysema and asthma, 104, or 2 per cent; acute and chronic articular rheumatism, 81, or 1.6 per cent; muscular rheumatism, 68, or 1.3 per cent; other causes or diseases, 367, or 7.2 per cent. To the pathologist, the significant fact brought out by these statistics is the large number of cases complicated by other diseases of the eyeball or of the conjunctive tissue membrane and the eyelids.

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[a] Verwaltungs-Berichte, Allgemeiner Knappshafts Verein zu Bochum, 1905–1913, Bochum, Germany, 1905–1913.

These additional observations further emphasize the practical importance of miners' nystagmus as an occupational disease. The modern tendency of including occupational diseases within the scope of workmen's compensation for accidents or injuries suggests the practical importance of a more extended consideration of the subject. As shown by the accompanying bibliography, there have been few useful and conclusive American contributions to the literature on nystagmus. Aside from the brief consideration of nystagmus in Thompson's treatise on occupational diseases, a still more limited consideration by Lloyd may be mentioned chiefly on account of two interesting illustrations of the constrained positions under which miners' nystagmus is, according to some authorities, most likely to occur. Such mining practices, however, are comparatively rare in the United States on account of the relative infrequency of narrow coal seams and the more extended use of coal-mining machinery. No reasons suggest themselves, however, why this peculiar affliction should be limited to mining districts of European countries and not be found in American coal-mining districts where, on account of the gaseous nature of the mines, the use of safety lamps is compulsory.

As shown by the European experience, the affliction is not likely to attract general attention until compensation is required to be paid for it. Llewellyn's estimate of compensation cost on account of miners' nystagmus in the United Kingdom, placed by him at nearly half a million dollars a year, is probably too high. However, if this country under liberal workmen's compensation laws should include compensation for industrial diseases, the problem of miners' nystagmus, aside from its humane considerations, will probably become much more important than it seems at present.

The information here presented should, however, serve the purpose of attracting general medical attention to an obscure affliction which, under existing conditions, may be erroneously diagnosed and neglected, when remedial measures would be of decided advantage to the miner and the mining industry.

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